

CALIFORNIA FISH AND GAME

"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

VOLUME 81

SUMMER 1995

NUMBER 3



California Fish and Game is published quarterly by the California Department of Fish and Game. It is a journal devoted to the conservation and understanding of California's flora and fauna. If its contents are reproduced elsewhere, the authors and the California Department of Fish and Game would appreciate being acknowledged.

Subscriptions may be obtained at the rate of \$15 (\$20 for foreign subscribers) per year by placing an order with the Editor, *California Fish and Game*, 4001 North Wilson Way, Stockton, California 95205-2486. Checks or money orders in U.S. dollars should be made out to *California Fish and Game*. Inquiries regarding subscriptions should be directed to the editors. Complimentary subscriptions are granted on an exchange basis.

California Department of Fish and Game employees may request complimentary subscriptions to the journal.

Please direct correspondence to:

David W. Kohlhorst or James J. Orsi
Co-Editors-in-Chief
California Fish and Game
4001 North Wilson Way
Stockton, California 95205-2486
e-mail: dkohlhor@delta.dfg.ca.gov
jorsi@delta.dfg.ca.gov



CALIFORNIA FISH AND GAME

VOLUME 81

SUMMER 1995

NUMBER 3



Published Quarterly by

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME
--LDA--

STATE OF CALIFORNIA
PETE WILSON, *Governor*

THE RESOURCES AGENCY
DOUGLAS P. WHEELER, *Secretary for Resources*

FISH AND GAME COMMISSION

Doug McGeoghegan, *President*
Richard Thieriot, *Vice-president*
Frank D. Boren, *Member*
Theodore Dutton, *Member*
Margie Phares, *Member*
Robert R. Treanor, *Executive Director*

DEPARTMENT OF FISH AND GAME

JACQUELINE E. SCHAFER, *Director*
C.F. Raysbrook, *Chief Deputy Director*
R.A. Bernheimer, *Deputy Director*
Banky E. Curtis, *Deputy Director*
Kassandra Fletcher, *Deputy Director*
Al Petrovich Jr., *Deputy Director*

Perry L. Herrgesell, Ph.D., *Chief* Bay-Delta Division
L. B. Boydstun, *Acting Chief* Marine Resources Division
Timothy C. Farley, *Chief* Inland Fisheries Division
Terry M. Mansfield, *Chief* Wildlife Management Division
John Turner, *Chief* Environmental Services Division
Susan A. Cochrane, *Chief* Natural Heritage Division
DeWayne Johnston, *Chief* Wildlife Protection Division
Richard Elliott, *Regional Manager* Redding
Ryan Broddrick, *Regional Manager* Rancho Cordova
Kenneth Aasen, *Acting Regional Manager* Yountville
Christopher Patin, *Acting Regional Manager* Fresno
Patty Wolf, *Acting Regional Manager* Long Beach

CALIFORNIA FISH AND GAME
EDITORIAL STAFF

David W. Kohlhorst and James J. Orsi, *Co-Editors-in-Chief* Bay-Delta
Walter Beer; Betsy C. Bolster; John Brode;
Ralph Carpenter; Arthur C. Knutson, Jr. Inland Fisheries
Vernon Bleich, Dan Yparraguirre Wildlife Management
Steve Crooke, Doyle Hanan, Ronald Warner Marine Resources
Donald E. Stevens Bay-Delta
Liam Davis, Peter T. Phillips Environmental Services

CONTENTS

Record of the Bigeye Trevally, *Caranx sexfasciatus*, and Mexican Lookdown, *Selene brevoorti*, with Notes on Other Carangids from California Robert N. Lea and H. J. Walker, Jr. 89

Current Distribution of the American Marten, *Martes americana*, in California Thomas E. Kucera, William J. Zielinski, and Reginald H. Barrett 96

Current Distribution of the Fisher, *Martes pennanti*, in California William J. Zielinski, Thomas E. Kucera, and Reginald H. Barrett 104

Accuracy of Cementum Age Assignments for Black Bears Jeffrey A. Keay 113

Black Bear Reproductive Rates in Yosemite National Park Jeffrey A. Keay 122

In Memoriam - David C. Zeiner 132

NOTICE OF SUBSCRIPTION RATE INCREASE

Effective with the 1996 volume, the subscription rate will be \$15 domestic and \$20 foreign. Checks or money orders in U.S. dollars should be made out to: *California Fish and Game* and sent to: Editors, *California Fish and Game*, 4001 North Wilson Way, Stockton, California 95205-2486.

ANNOUNCEMENT

41st ANNUAL INSTITUTE IN WATER POLLUTION CONTROL

MANHATTAN COLLEGE
Riverdale, New York, USA

3-7 JUNE 1996

Manhattan College's 41st annual Institute in Water Pollution Control will take place 3-7 June 1996 in the Manhattan College Leo Engineering Building, Riverdale, New York. Two concurrent courses will be offered: *Modern Eutrophication Modeling and Treatment of Municipal, Hazardous, and Toxic Wastewaters*. These week-long courses have much to offer young engineers and seasoned professionals who have not been able to stay abreast of the rapidly changing field. Set in a classroom atmosphere, the courses allow for dialog between lecturer and participants. The fee per course is \$1,150 and includes a set of notes for each attendee.

For a brochure or additional information, contact: Ms. Lucia Chiocchio, Program Coordinator, Manhattan College, Environmental Engineering Department, Riverdale, New York 10471; Phone (718) 920-0277; FAX (718) 543-7924.

**RECORD OF THE BIGEYE TREVALLY,
CARANX SEXFASCIATUS,
AND MEXICAN LOOKDOWN,
SELENE BREVOORTI,
WITH NOTES ON OTHER CARANGIDS FROM CALIFORNIA**

ROBERT N. LEA

California Department of Fish and Game
Marine Resources Division
20 Lower Ragsdale Drive
Monterey, California 93940

and

H. J. WALKER, JR.

Scripps Institution of Oceanography
University of California, San Diego 0208
La Jolla, California 92093

Two species of jacks (family Carangidae), bigeye trevally, *Caranx sexfasciatus*, and Mexican lookdown, *Selene brevoorti*, are recorded for the first time from the marine waters of California. In addition, a size record for the green jack, *Caranx caballus*, is documented. A table listing the 14 species of jacks known from California, their zoogeographic affinities and status is included. The question concerning the occurrence of these jacks (and other Panamic fishes), whether through man's intervention (inadvertent or purposeful introduction) or by natural movement, is considered.

INTRODUCTION

Until now, 12 species of jacks (Carangidae) have been known from the Pacific coast of the United States, all of which occur in California (Robins et al. 1991a) (Table 1). In addition, the leatherjack, *Oligoplites saurus*, has been reported from California by several authors (Fitch and Lavenberg 1971, Miller and Lea 1972, Hubbs et al. 1979, and others); however, this record is suspect (Robins et al. 1980: 83) and is not included herein. In this paper we document the occurrence of two additional species of jacks from California, the bigeye trevally, *Caranx sexfasciatus* Quoy and Gaimard, 1825, and the Mexican lookdown, *Selene brevoorti* (Gill, 1863) (Figs. 1 and 2). We also report a range extension for the green jack, *Caranx caballus*, to central California and discuss the zoogeographic relationship of the 14 species of jacks now known from California.

RESULTS

During November 1990, Michael D. Irey, a commercial mullet fisherman, caught several unfamiliar jacks in a gill net at the south end of San Diego Bay near the San

Table 1. Species of jacks, family Carangidae, known from California, with their zoogeographic affinity and status.

Scientific <u>name</u>	Common <u>name</u>	Zoogeographic <u>affinity</u>	Status in <u>California</u>
<i>Caranx caballus</i>	green jack	Tropical	Uncommon
<i>Caranx caninus</i>	Pacific crevalle jack	Tropical	Rare - one record
<i>Caranx sexfasciatus</i>	bigeye trevally	Tropical	<i>Reported</i> this paper
<i>Chloroscombrus orqueta</i>	Pacific bumper	Tropical	Rare - fewer than 10
<i>Decapterus scombrinus</i>	Mexican scad	Tropical	Uncommon
<i>Naucrates ductor</i>	pilotfish	Tropical	Uncommon
<i>Selene brevoorti</i>	Mexican lookdown	Tropical	<i>Reported</i> this paper
<i>Selene peruviana</i> ^{a, b}	Pacific moonfish	Tropical	Rare - one record
<i>Seriola lalandi</i>	yellowtail	Warm-temperate	Important sportfish
<i>Seriola rivoliana</i>	almaco jack	Tropical	Rare
<i>Trachinotus paitensis</i> ^b	paloma pompano	Tropical	Rare - one record
<i>Trachinotus rhodopus</i> ^b	gafftopsail pompano	Tropical	Rare - one record
<i>Trachurus symmetricus</i>	jack mackerel	Broadly temperate	Important commercially
<i>Uraspis secunda</i>	cottonmouth jack	Tropical - oceanic	Rare - two records

^a Listed by Radovich (1961) as *Vomer declivifrons*. Robins et al. (1980:83) explain the nomenclatural change to *Selene peruviana*.

^b First recorded from California during 1957-59 warm-water period (El Niño condition) by Radovich (1961).

Diego Gas and Electric Company South Bay Electric Generating Facility. Water temperature is higher at this site than in the rest of San Diego Bay due to discharge of warm water from the facility. Five jacks were saved for our identification. Two were green jack and three were bigeye trevally. The bigeye trevally is broadly distributed in tropical waters throughout the Indian and Pacific oceans (Berry et al. 1981, Laroche et al. 1984, Robins et al. 1991b), but heretofore unknown from California. Information on this species from the eastern Pacific is limited and until recently the species from this geographic region was listed under the binomen *Caranx marginatus* Gill, 1866 (Jordan and Evermann 1896, Walford 1937). Walford (1974:14) noted without comment a change in scientific name to *Caranx sexfasciatus*, but attributed the species to Eydoux and Souleyet [sic] and suggested the common name Indo-Pacific horse-eye jack. Berry et al. (1981) list *C. marginatus*, as well as two other nominal species of *Caranx* (*C. elacate* and *C. forsteri*), as junior synonyms of *C. sexfasciatus*.

The green jack is typically a smaller species of 25-30 cm total length (TL) and occasionally enters the recreational catch in southern California (S. Crooke, California Department of Fish and Game, pers. comm.). During the El Niño event of

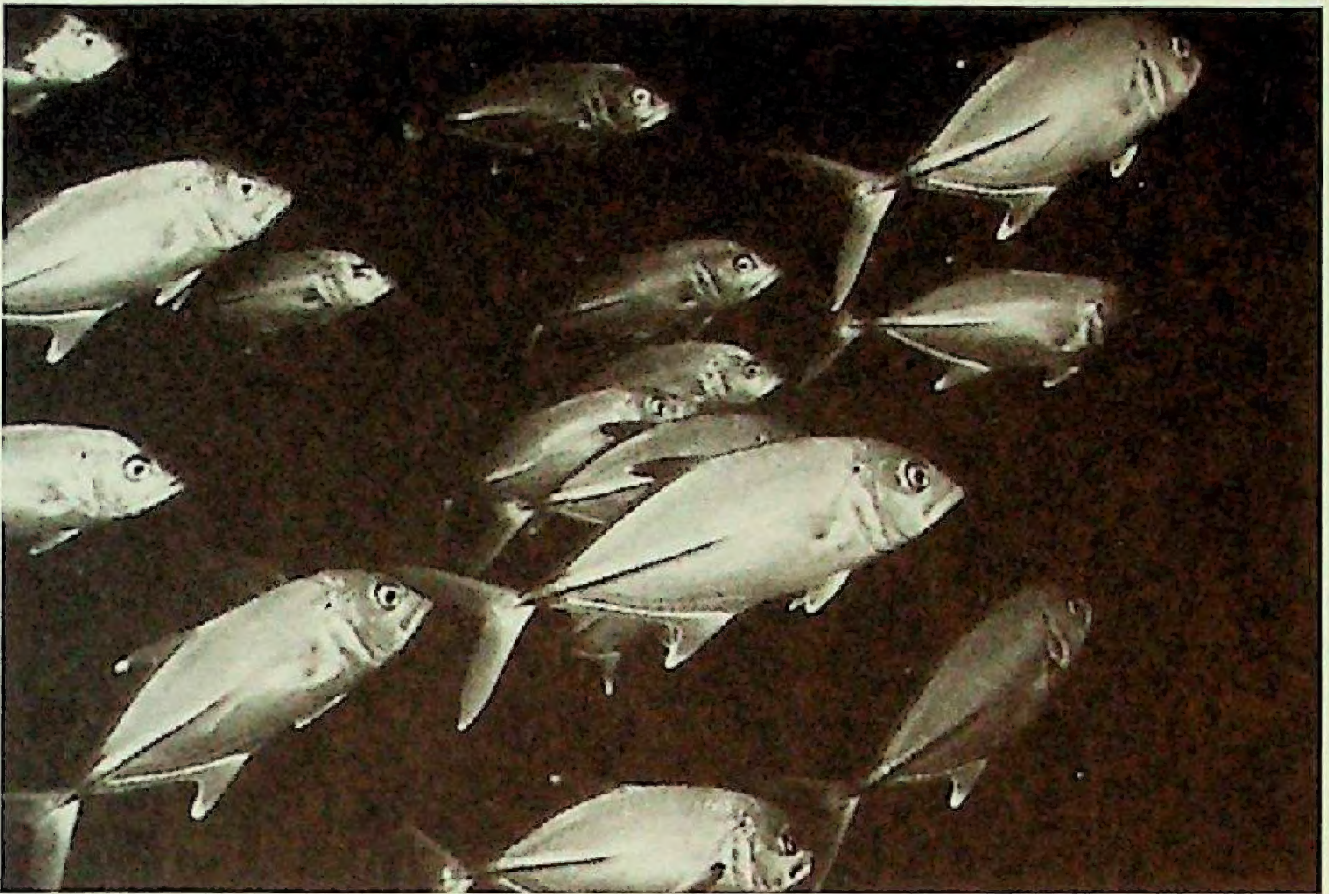


Figure 1. School of bigeye trevally, *Caranx sexfasciatus*, at Revillagigedo Islands, Mexico. Note white edging on tips of dorsal and anal fins and black "ear" spot, distinguishing field characters. Photograph by Daniel W. Gotshall.

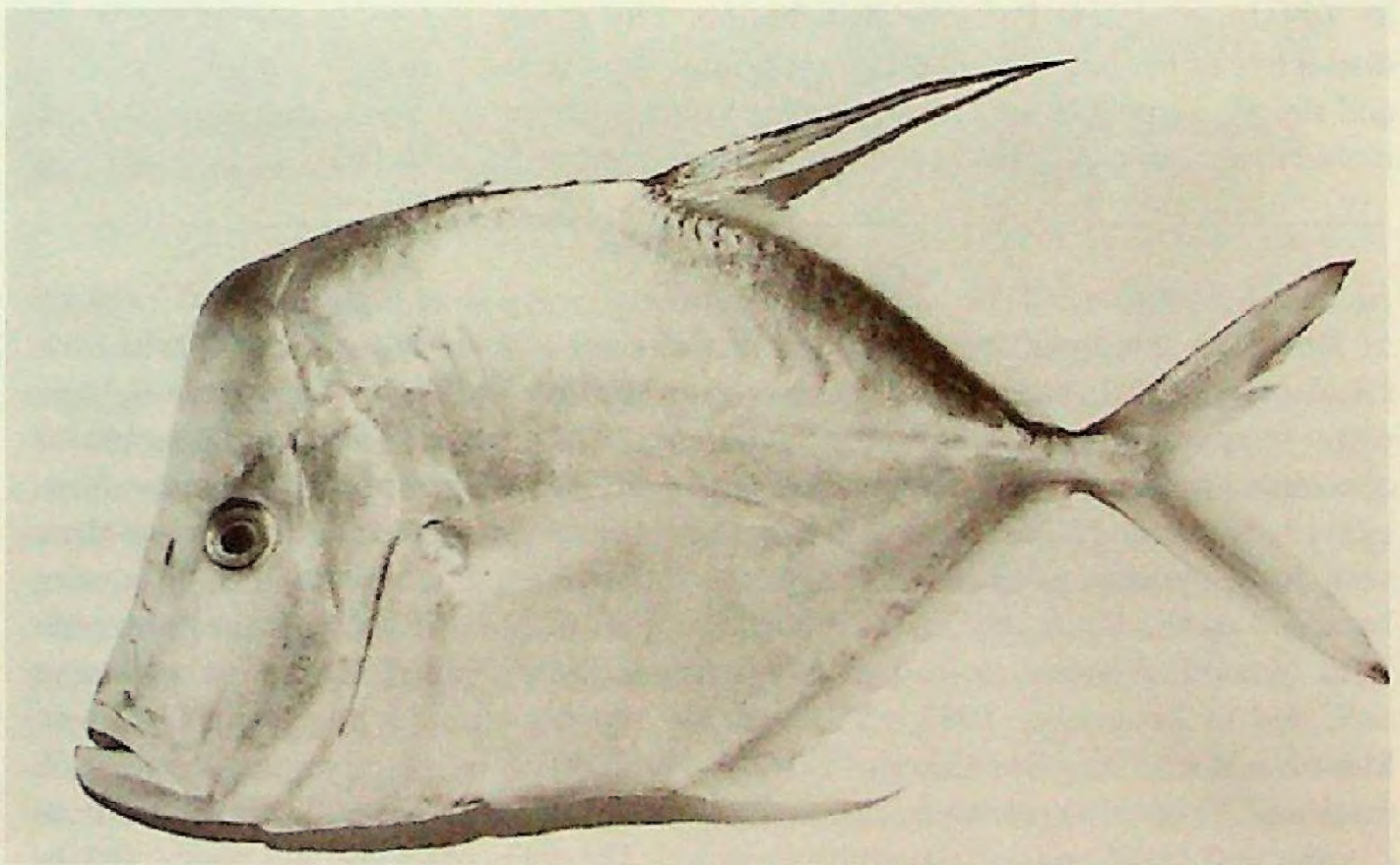


Figure 2. Mexican lookdown, *Selene brevoorti*, from San Diego Bay, SIO 93-192. Photograph by Richard H. Rosenblatt.

1982-84, green jacks were taken in fair numbers off the Port San Luis pier and breakwater at Morro Bay, San Luis Obispo County (S. Owen, California Department of Fish and Game, pers. comm.). Also, in July 1983 several were caught by anglers as far north as Sea Cliff State Beach, Monterey Bay (one specimen deposited at California Academy of Sciences, CAS 54926). The known range of this species is thus extended from Santa Cruz Island approximately 390 km north to Monterey Bay. Although green jack from San Diego Bay might not be considered extraordinary, one individual is noteworthy based on size. This specimen, deposited at Scripps Institution of Oceanography (SIO 91-112), measured 50.5 cm TL (19.9 inches), which substantially exceeds Walford's (1937) characterization as "a small fish, scarcely exceeding 15 inches in length..." and Miller and Lea's (1972) listed maximum length of "15 in."

The bigeye trevally is similar in general appearance to the green jack, although it attains greater size (to 75.7 cm fork length, Berry et al. 1981). Its key distinguishing features are: i) white edging on the outer tips of the dorsal and anal fins, ii) black "ear" spot, and iii) low gill raker count (<30 total rakers). Counts and measurements for the three bigeye trevally from San Diego Bay are presented in Table 2. These three specimens are deposited in the Marine Vertebrates Collection at Scripps Institution of Oceanography (SIO 91-112).

On 4 February 1993, Michael Irey, again fishing for mullet in south San Diego Bay, caught a Mexican lookdown. The fish was taken by gill net in water approximately 2.5 m deep. This represents the first record of this species for California; the previous range had been given as Magdalena Bay to Peru (Walford 1974, Robins et al. 1991b), a typical Panamic distribution. The genus *Selene* is one of the most distinctive of the jacks in general morphology with its deep, highly compressed body and steeply sloping head. Counts and measurements for the San Diego specimen are included in Table 2. This specimen is catalogued as SIO 93-192.

DISCUSSION

From the standpoint of zoogeographic relationship, the 14 species of jacks now known from California can be categorized as follows: 12 tropical, one warm-temperate, and one broadly temperate. Of the tropical species, all must be considered as expatriates and in the majority of cases are known from one or, at most, a few records. The Pacific crevalle jack, *Caranx caninus*; Pacific moonfish, *Selene peruviana*; paloma pompano, *Trachinotus paitensis*; and gafftopsail pompano, *Trachinotus rhodopus*, are based on single records from California. The cottonmouth jack, *Uraspis secunda*, is known from two records (Fitch 1972 and a specimen collected in September 1983 off Oceanside and deposited at the Natural History Museum of Los Angeles County, LACM 44982). The two temperate species, jack mackerel, *Trachurus symmetricus*, and yellowtail, *Seriola lalandi*, are much more common off California, as would be expected. The jack mackerel has been a fish of commercial importance since the late 1800s (Jordan and Evermann 1902) and can be an important component of the sportfish catch, especially by pier and skiff

Table 2. Counts and measurements for three specimens of bigeye trevally, *Caranx sexfasciatus*, and one specimen of Mexican lookdown, *Selene brevoorti*, from San Diego Bay.

Counts and measurements	<i>Caranx sexfasciatus</i>			<i>Selene brevoorti</i>
Standard length ^a	231.0	247.6	590	230
Total length	1.24	1.25	1.19	1.24
Fork length	1.07	1.07	1.07	1.07
Head length	0.31	0.30	0.27	0.41
Eye diameter	0.07	0.08	0.06	0.06
Snout length	0.09	0.09	0.07	0.21
Maxillae length	0.14	0.14	0.13	0.12
Pectoral length	0.32	0.36	0.32	0.40
Predorsal length	0.40	0.39	0.37	0.58
Preanal length	0.51	0.51	0.49	0.53
Length to D2	0.57	0.57	0.52	0.74
Length to A2	0.57	0.59	0.54	--
Body depth at D2	0.37	0.37	0.30	0.54
Dorsal fin elements ^b	VII+I,20	VIII+I,20	VII+I,19	VII+I,21
Anal fin elements	II+I,17	II+I,16	II+I,16	I,17
Lateral line scutes	31	29	29	none
Gill rakers (left) ^c	7+16=23	7+16=23	6+15=21	8+33=41

^a Standard length given in millimeters. All other measurements are given as proportion of standard length.

^b Dorsal spine count represents only those spines that could be visually detected or probed. Embedded spines that would be discerned by radiograph are not enumerated.

^c Only developed rakers enumerated. In *Caranx sexfasciatus* two or three rudimentary rakers are forward of anterior-most developed raker on lower limb of gill arch.

anglers. The yellowtail is of great economic importance to the sportfishing fleet in southern California, principally the port of San Diego (Baxter et al. 1960). It is caught in greatest numbers during warm-water periods, such as the El Niño oceanographic phenomena of 1957-59, 1982-84, and 1992-93.

The occurrence of Panamic fishes off California raises the question as to their mode of arrival. In recent years an increasing number of long-range sport fishing vessels and private yachts have traveled to the Sea of Cortez, Revillagigedo Islands, and points farther south. Instances of vessels returning with tropical organisms in their bait wells and holds are of concern and may occur more frequently than suspected.

Whether the bigeye trevally and Mexican lookdown reached California in this manner or arrived through natural movement, either as adults or initially as larvae by way of larval drift, cannot be unequivocally determined. However, it is our opinion that the occurrence of these jacks in San Diego Bay most likely is related to natural movements of the species in relation to warm-water oceanographic conditions. This

hypothesis is consistent with the pattern of other panamic species (e.g. Cortez angelfish, *Pomacanthus zonipectus*; stone scorpionfish, *Scorpaena mystes*; Pacific seahorse, *Hippocampus ingens*; Cortez grunt, *Haemulon flaviguttatum*; swallow damselfish, *Azurina hirundo*; etc.) which were recorded off California following the El Niño event of 1982-84 and succeeding warm-water years.

ACKNOWLEDGMENTS

We are especially grateful to M.D. Irey who collected the specimens and brought them to our attention. We thank R.H. Rosenblatt for providing the photograph of the Mexican lookdown and for reviewing the manuscript. We also thank D.W. Gotshall for the photograph of the bigeye trevally, C.C. Swift and C.W. Haugen for their critique, and C. Klepadlo for curatorial assistance. This study was supported in part by the Sport Fish Restoration Act.

LITERATURE CITED

- Baxter, J.L. and a staff of associates. 1960. A study of the yellowtail *Seriola dorsalis* (Gill). California Department of Fish and Game, Fish Bulletin 110.
- Berry, F.H., W.F. Smith-Vaniz, and J.B. Moberly. 1981. Identification of trevallies or crevalles (genus *Caranx*) of the Indian and Pacific oceans. International Game Fish Association (Special Publication).
- Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America. The Peterson Field Guide Series 28, Houghton Mifflin Co., Boston, Massachusetts, USA.
- Fitch, J.E. 1972. The cottonmouth jack, *Uraspis secunda*, added to the marine fauna of California. California Fish and Game 58:245-246.
- Fitch, J.E. and R.J. Lavenberg. 1971. Marine food and game fishes of California. University of California Press, Berkeley, California, USA.
- Hubbs, C.L., W.I. Follett, and L.J. Dempster. 1979. List of the fishes of California. California Academy of Sciences, Occasional Papers No. 133.
- Jordan, D.S. and B.W. Evermann. 1896. The fishes of North and Middle America. Bulletin of the United States National Museum, No. 47, Part 1.
- Jordan, D.S. and B.W. Evermann. 1902. American food and game fishes. Doubleday, Page & Co., New York, New York, USA.
- Laroche, W.A., W.F. Smith-Vaniz, and S.L. Richardson. 1984. Carangidae: development. Pages 510-522 in: Ontogeny and systematics of fishes. American Society of Ichthyologists and Herpetologists, Special Publication No. 1.
- Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fish Bulletin 157.
- Radovich, J. 1961. Relationships of some marine organisms of the northeast Pacific to water temperatures particularly during 1957 through 1959. California Department of Fish and Game, Fish Bulletin 112.
- Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. Common and scientific names of fishes from the United States and Canada, fourth edition. American Fisheries Society Special Publication 12.

- Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991a. Common and scientific names of fishes from the United States and Canada, fifth edition. American Fisheries Society Special Publication 20.
- Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991b. World fishes important to North Americans exclusive of species from the continental waters of the United States and Canada. American Fisheries Society Special Publication 21.
- Walford, L.A. 1937. Marine game fishes of the Pacific Coast from Alaska to the Equator. University of California Press, Berkeley, California, USA.
- Walford, L.A. 1974. Marine game fishes of the Pacific Coast from Alaska to the Equator. Reprint of the 1937 edition for the Smithsonian Institution by T.F.H. Publications, Inc., Neptune, New Jersey, USA.

Received: 15 November 1994

Accepted: 22 March 1995

CURRENT DISTRIBUTION OF THE AMERICAN MARTEN, *MARTES AMERICANA*, IN CALIFORNIA

THOMAS E. KUCERA

Department of Environmental Science, Policy, and Management
University of California
Berkeley, California 94720

WILLIAM J. ZIELINSKI

USDA Forest Service
Pacific Southwest Research Station
and Department of Wildlife
Humboldt State University
Arcata, California 95521
and

REGINALD H. BARRETT

Department of Environmental Science, Policy, and Management
University of California
Berkeley, California 94720

We describe the current distribution of the American marten, *Martes americana*, in California based on field surveys conducted between 1989 and 1995 that used either sooted track-plates or cameras. The Sierra Nevada marten, *M. a. sierrae*, occupies much of its historic range from northwestern Shasta County to the southern Sierra Nevada. The Humboldt marten, *M. a. humboldtensis*, in Humboldt and Del Norte counties, is extremely rare or extinct. We recommend defining the current distributions of rare or secretive species by techniques that produce verifiable records rather than relying on historic or anecdotal reports.

INTRODUCTION

The American marten, *Martes americana*, a small (500-1200 g) mustelid endemic to North America, historically occurred in forests across the continent from the tree line in the north to montane areas of central California and northern New Mexico (Hagmeier 1956, Hall 1981, Gibilisco 1994). In the eastern and Great Lakes regions of North America, the southern limit of distribution of American marten has retreated northward as a result of habitat loss and heavy trapping. Some of this range is being reoccupied, both by natural expansions and with the aid of translocations (Gibilisco 1994). In western North America, there is concern about the effects of loss and fragmentation of mature coniferous forests on American marten because of its association with these forests (Buskirk and Powell 1994).

However, recent data on regional distribution in the western United States are few.

Based on specimens taken at known localities in California, Grinnell et al. (1937:209) concluded that "two well-marked races occur within the State." The Humboldt marten, *M. a. humboldtensis*, occurred in the coastal redwood, *Sequoia sempervirens*, zone from the Oregon border south to Fort Ross, Sonoma County. The Sierra Nevada marten, *M. a. sierrae*, occurred from Trinity and Siskiyou counties east to Mt. Shasta and south through the Sierra Nevada to Tulare County.

Empirical data on the distribution of American marten in California since Grinnell et al. (1937) are few. Trapping data indicate that martens were taken in at least 21 counties, including Humboldt and Del Norte, until trapping was prohibited in 1953 (California Department of Fish and Game [CDFG], unpublished data). Twining and Hensley (1947) expressed concern about the status of the Humboldt marten. Data on the occurrence of American marten are not included in the California Natural Diversity Data Base (E. Burkett, CDFG, pers. comm.). Yocum (1974) presented locations of reported sightings of American martens in northern California between 1961 and 1973 and Schempf and White¹ (1977) summarized existing information on their distribution throughout the state. The most recent description of the distribution of American marten in North America (Gibilisco 1994), including California, was based on responses to a survey mailed to agency personnel in 1990-91. Thus, none of these more recent documents is based on field surveys or locations of verifiable specimens, photographs, or tracks.

Since 1989, several efforts have occurred throughout much of California to document empirically the distribution of American marten and other carnivores of conservation interest such as the fisher, *M. pennanti*, and wolverine, *Gulo gulo*, through standardized detection techniques (Zielinski and Kucera² 1995). These techniques produce a verifiable record, either a photograph or a track, of the presence of an animal at a point location. The objectives of the present paper are to describe the current distribution of the American marten in California based on these recent surveys and to document that such efforts are feasible and valuable for management of rare or secretive carnivores.

METHODS

Detections of American martens reported here were produced by one of three techniques: baited track-plates (Barrett 1983, Fowler and Golightly³ 1993,

¹ Schempf, P.F. and M. White 1977. Status of six furbearer populations in the mountains of northern California. Unpublished report, USDA Forest Service, California Region, San Francisco, California, USA.

² Zielinski, W. J. and T. E. Kucera, editors. 1995. American marten, fisher, lynx, and wolverine: survey methods for their detection. USDA Forest Service General Technical Report PSW-GTR-157.

³ Fowler, C. and R. Golightly. 1993. Fisher and marten survey techniques on the Tahoe National Forest. Final Report, Agreement No. PSW-90-0034CA, Humboldt State University and USDA Forest Service.

Zielinski⁴ 1995); 110-size remote camera stations (Jones and Raphael⁵ 1993, Kucera et al.⁶ 1995); and remote, 35-mm camera stations (Kucera and Barrett 1993a, Kucera et al.⁶ 1995). These techniques produce either a track or a photograph from a known location.

The data came from three types of surveys: i) local studies to determine animal presence within an area of a potential habitat alteration such as a timber sale or recreational development, ii) regional studies to determine animal distribution across one or several watersheds, and iii) statewide efforts to detect rare carnivores. Many of the first type of survey were conducted according to the Forest Service Region 5 protocol (Zielinski⁷ 1992) in which ≥ 10 track-plate stations were installed at 0.8-km intervals along roads in areas of proposed timber sales. Surveys of the second type were conducted across a landscape with detection stations arrayed in a grid with nodes 1-1.6 km apart. The third type included individual camera stations placed in areas of historic wolverine range in an attempt to detect wolverines (Kucera and Barrett 1993b). Although the first two types included multiple detection stations in a single survey, they will be represented as one location. Surveys of the third type always comprised single detection stations. In some cases surveys were conducted with the intention of detecting fishers, and thus were at elevations and in habitats where martens are not expected to occur (Schempf and White¹ 1977, Buskirk and Powell 1994).

All work was conducted from October 1989 to March 1995. Surveys occurred through much of the historic range of the American marten from Del Norte and Humboldt counties east to Lassen County and as far south as northern Kern County. Details on specific locations, techniques, and results are on file at the Department of Environmental Science, Policy, and Management at the University of California, Berkeley, California, and the Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, California.

RESULTS

We report data from 479 survey locations, ranging from Del Norte and Siskiyou counties to Kern County (Figs. 1 and 2). American martens were detected at 114 of

⁴ Zielinski, W.J. 1995. Track-plates. Pages 67-89 *in*: W.J. Zielinski and T.E. Kucera, editors. American marten, fisher, lynx, and wolverine: survey methods for their detection. USDA Forest Service General Technical Report PSW-GTR-157.

⁵ Jones, L.L.C. and M.G. Raphael. 1993. Inexpensive camera systems for detecting martens, fishers, and other animals: guidelines for use and standardization. USDA Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-306.

⁶ Kucera, T.E., A.S. Soukkala, and W.E. Zielinski. 1995. Photographic bait stations. Pages 25-65 *in*: W.J. Zielinski and T.E. Kucera, editors. American marten, fisher, lynx, and wolverine: survey methods for their detection. USDA Forest Service General Technical Report PSW-GTR-157.

⁷ Zielinski, W.J. 1992. A survey protocol to monitor forest carnivores in proposed management activity areas. Unpublished report, USDA Forest Service, Pacific Southwest Forest and Range Experimental Station, Arcata, California, USA.

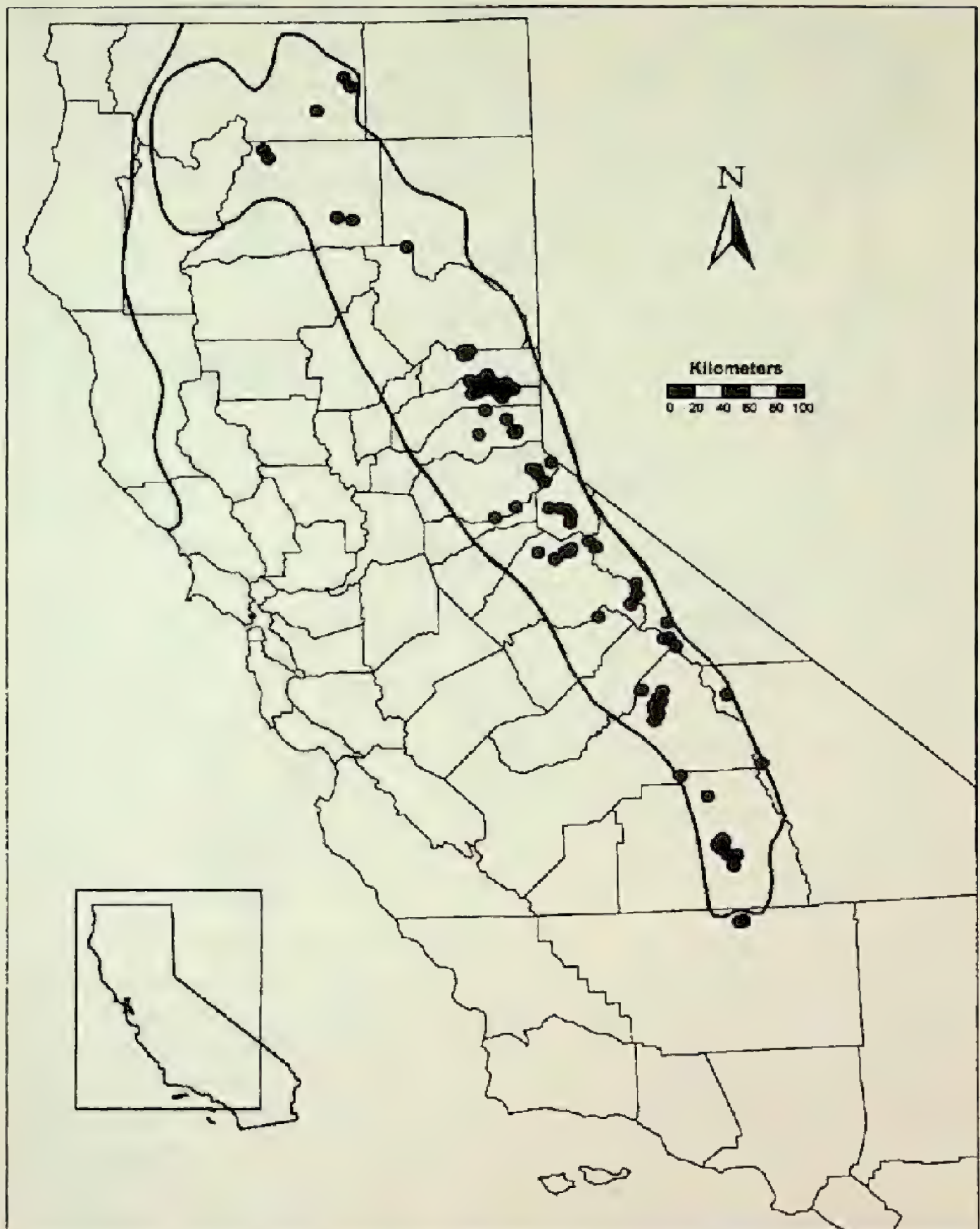


Figure 1. Locations of surveys in California that detected American martens, 1989-1995. Survey locations included those with a single detection device, such as a remote camera, and those with multiple devices, such as track-plate boxes along a transect. Outlines of counties are also shown. Heavy irregular lines enclose the ranges of *M. a. humboldtensis* (northwest California) and *M. a. sierrae* described by Grinnell et al. (1937).

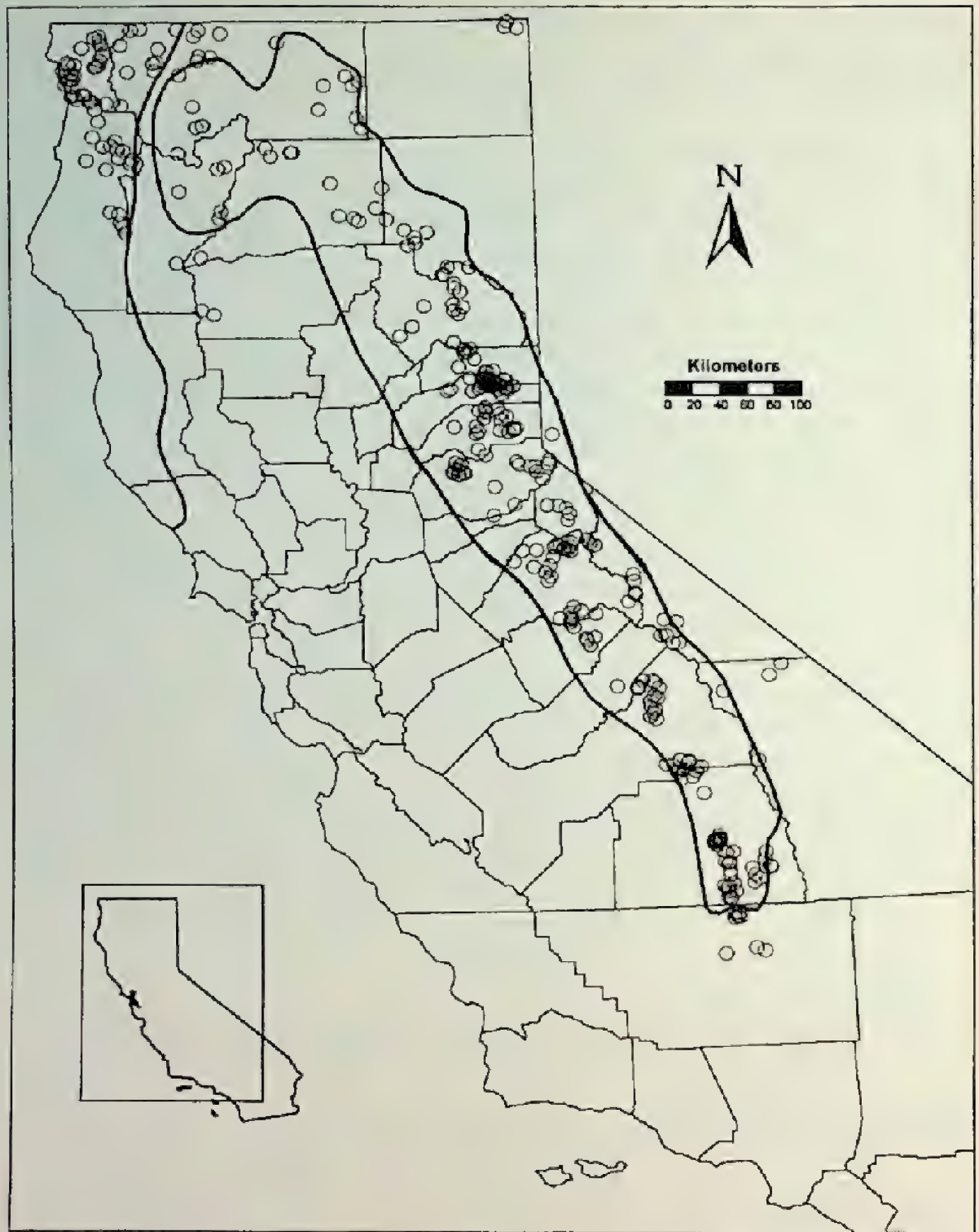


Figure 2. Locations of surveys for American martens in California, 1989-1995. Survey locations include those with a single detection device, such as a remote camera, and those with multiple devices, such as track-plate boxes along a transect. Outlines of counties are also shown. Heavy irregular lines enclose the ranges of *M. a. humboldtensis* (northwest California) and *M. a. sierrae* described by Grinnell et al. (1937).

these, from eastern Siskiyou and northwestern Shasta counties through the western slope of the Sierra Nevada to northern Kern County. American martens were detected on the eastern slope of the Sierra Nevada as far south as central-western Inyo County. No American martens were detected in Del Norte or Humboldt counties. The several clusters of detections reflect intensive work in those particular areas and do not necessarily indicate American marten population density.

DISCUSSION

The American marten at present appears to occupy much of its historic range in California, particularly in the Sierra Nevada and south and east of the Trinity Mountains. We emphasize that the data presented here indicate the current regional distribution of American marten in California. These data do not address trends in populations or habitat or the habitat requirements of American marten; such information can be produced only by a more planned and systematic approach to sampling.

However, noticeable gaps exist in the distribution of American marten. The most serious is that no martens were detected in the range of the Humboldt marten in Del Norte and Humboldt counties despite numerous survey efforts there (Fig. 2). Other recently completed surveys in Del Norte and Humboldt counties, the results of which are not included here, also failed to detect martens (R. Golightly, Humboldt State University, pers. comm.). We have no quantitative measure of the probability that negative results in a survey mean in fact that no American martens occur in a particular survey area. However, the ease with which American martens are typically detected at bait stations strongly suggests that Humboldt martens are at best extremely rare at the locations where surveys occurred, and may be extinct. Negative results also occurred in central Plumas and southern Tulare counties at numerous locations.

Given its apparent rarity, the Humboldt marten should be included in ecosystem management and biodiversity planning efforts in the coastal redwood zone along with listed, forest-dwelling species such as the marbled murrelet, *Brachyramphus marmoratus*, and northern spotted owl, *Strix occidentalis*, and candidates for listing such as the Pacific fisher. If future surveys fail to detect the Humboldt marten, we suggest that the CDFG consider reintroduction of American martens to areas of remaining habitat within the historic range of the Humboldt marten such as Redwood National Park and Humboldt Redwoods State Park.

There are several omissions in areas surveyed. One is in southern Humboldt and northern Mendocino counties, where Yocum (1974) reported sightings of Humboldt martens in 1961 and 1971, respectively. The higher-elevation areas of Trinity County have not been surveyed, yet the habitat suggests that American martens could occur there. Finally, forested areas of the White Mountains in eastern Mono and northern Inyo counties, reported by Schempf and White¹ (1977) to have American martens, have not been surveyed adequately. Gibilisco (1994) discussed the importance of American marten populations that occur on isolated mountain ranges

to the understanding of its distributional dynamics; documenting American marten presence in the isolated White Mountains may contribute to that understanding in one of the most southerly parts of its range.

We emphasize that the data reported here are based on verified tracks or photographs of American martens; they do not include reports of sightings. Sighting data need to be treated cautiously because they are impossible to verify, although reliability indices can be developed (Aubry and Houston 1992; E. Burkett, pers. comm.). For example, there are locations where surveys failed to confirm the existence of American martens but where National Forests report a number of recent sightings (e.g. Six Rivers National Forest). Although several of these reports are unreliable (G. Schmidt, Six Rivers National Forest, pers. comm.), others include areas that have yet to be surveyed and may have merit. We recommend that federal and state agencies support the survey of rare carnivores using detection methods that can produce verifiable results (Zielinski and Kucera², 1995). Reliable sighting data should be used to augment, not substitute for, surveys using cameras or track-plates.

The American marten in the early 1990s occurs in much of its historic range in California with the apparent exception of the coastal redwood areas. This presents land managers with the opportunity to understand the ecology and habitat requirements of American marten, and the effects of management activities on it, in what is presently a non-crisis environment. We advocate that this opportunity not be missed.

ACKNOWLEDGMENTS

Work reported here was supported by the CDFG; the California Department of Forestry and Fire Protection; the USDA (USFS); the University of California, Berkeley Agricultural Experiment Station (Project 5410MS); Humboldt State University; Pacific Gas and Electric Company; the USDI Bureau of Land Management; and the Nature Conservancy. R. Schlorff and E. Burkett of CDFG and D. MacFarlane of USFS were particularly helpful. We thank C. Ogan, R. Truex, K. Busse, and I. Timossi for assistance in data management. S. A. Laymon and others from the Kern River Research Center provided data from work in the Sierra and Sequoia National Forests and D. Bise contributed data from work in several state forests. Numerous USFS biologists and researchers have generously cooperated by conducting the surveys and submitting their work to us. We thank the personnel of these organizations and other volunteers for their work in the field.

LITERATURE CITED

- Aubry, K.B. and D.B. Houston. 1992. Distribution and status of the fisher (*Martes pennanti*) in Washington. Northwest Naturalist 73:69-79.
- Barrett, R.H. 1983. Smoked aluminum track plots for determining furbearer distribution and abundance. California Fish and Game 69:188-190.

- Buskirk, S.W. and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pages 283-296 *in*: S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. Martens, sables, and fishers: biology and conservation. Cornell University Press, Ithaca, New York, USA.
- Gibilisco, C.J. 1994. Distributional dynamics of modern *Martes* in North America. Pages 59-71 *in*: S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. Martens, sables, and fishers: biology and conservation. Cornell University Press, Ithaca, New York, USA.
- Grinnell, J., J.S. Dixon, and J.M. Linsdale. 1937. Furbearing mammals of California, volume 1. University of California Press, Berkeley, California, USA.
- Hagmeier, E.M. 1956. Distribution of marten and fisher in North America. Canadian Field-Naturalist 70:149-168.
- Hall, E.R. 1981. The mammals of North America, second edition. John Wiley and Sons, New York, New York, USA.
- Kucera, T.E. and R.H. Barrett. 1993a. The Trailmaster camera system for detecting wildlife. Wildlife Society Bulletin 21:505-508.
- Kucera, T.E. and R.H. Barrett. 1993b. The California Cooperative Wolverine Survey. Transactions of the Western Section of the Wildlife Society 28:49-53.
- Twining, H. and A. Hensley. 1947. The status of pine martens in California. California Fish and Game 33:133-137.
- Yocum, C.F. 1974. Status of marten in northern California, Oregon and Washington. California Fish and Game 60:54-57.

Received: 12 October 1994

Accepted: 29 March 1995

CURRENT DISTRIBUTION OF THE FISHER, *MARTES PENNANTI*, IN CALIFORNIA

WILLIAM J. ZIELINSKI
USDA Forest Service
Pacific Southwest Research Station
and Department of Wildlife
Humboldt State University
Arcata, California 95521

THOMAS E. KUCERA and REGINALD H. BARRETT
Department of Environmental Science, Policy, and Management
College of Natural Resources
University of California
Berkeley, California 94720-3114

We describe the 1989-1994 distribution of the fisher, *Martes pennanti*, in California based on the results of detection surveys that used either sooted track-plates or cameras. Fishers were detected in two regions of the state: the northwest and the southern Sierra Nevada. Despite considerable survey effort, neither fisher tracks nor photographs were collected in the area between Mt. Shasta and Yosemite National Park. This represents a significant breach in the distribution formerly interpreted as continuous. Detection survey results suggest that the population in the southern Sierra Nevada may be isolated from populations to the north. We recommend that additional survey effort be focused on the southern Cascades and northern Sierra Nevada and that forests of the Sierra Nevada be managed to encourage the movement of fishers between these areas. We also recommend that descriptions of the current distributions of uncommon carnivores be based on techniques that produce verifiable records rather than summaries of incidental sightings.

INTRODUCTION

The fisher, *Martes pennanti*, historically occurred in forests from British Columbia to Quebec and as far south as Tennessee, Illinois, Wyoming, and central California (Hagmeier 1956, Gibilisco 1994, Graham and Graham 1994). Although the fisher became uncommon in the east and midwest early in this century, it has recovered throughout much of its eastern range due to the regulation of trapping, the increase in forest lands due to farmland abandonment, and reintroductions (Powell 1993). In the western United States, the fisher once occurred throughout the northern Rocky Mountains, Cascade Mountains, Coast Ranges, and Sierra Nevada, but significant

gaps in this distribution now occur (Gibilisco 1994, Powell and Zielinski¹ 1994).

The status and distribution of the fisher in California have been described on several occasions in the 20th Century. Grinnell et al. (1937) summarized 1919-1924 trapping records and anecdotal accounts and described the fisher as occurring in the northern Coast Range, Klamath (Siskiyou, Trinity, and Marble) Mountains, southern Cascades, and western slope of the Sierra Nevada. Yocom and McCollum (1973) summarized incidental fisher sightings in northwestern California but did not address the distribution in the southern Cascades and Sierra Nevada. Schempf and White² (1977) reviewed agency wildlife observations and concluded that fishers were "common and increasing" in the extreme northwestern counties, "decreasing" in the southern Sierra Nevada and "persisting at a very low density" in the northern Sierra Nevada. Gould³ (1987) updated the Schempf and White database of sightings and concluded that fishers were "no longer distributed throughout their historic range in California." Information contributed by California Department of Fish and Game (CDFG) personnel in response to a mail survey conducted by Gibilisco (1994) indicated concern about the persistence of fishers in the Sierra Nevada.

Of the efforts described above, only the locations of trapped animals (Grinnell et al. 1937) represent observations that could be independently verified. Although the reliability of sightings can be screened on the basis of the qualifications of the observer (e.g. Aubry and Houston 1992), fishers can be easily mistaken for a number of other carnivores, especially American martens, *M. americana*, even by experienced observers (W. Zielinski, pers. obs.; R. Golightly, Humboldt State University, Arcata, California, pers. comm.).

Recent development of nonlethal detection methods permits the collection of verifiable evidence of occurrence, either tracks or photographs, from forest carnivores attracted to scent and bait (Barrett 1983, Raphael 1994, Fowler⁴ 1995, Zielinski and Kucera⁵ 1995). Since 1989, several efforts have occurred throughout the mountains of northern and central California to document empirically the distribution of fishers and other mammalian carnivores of conservation interest, such as the

¹ Powell, R.A. and W.J. Zielinski. 1994. The fisher. Pages 38-73 in: L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon and W.J. Zielinski, editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. USDA Forest Service Rocky Mountain Research Station General Technical Report RM-GTR-254.

² Schempf, P.F. and M. White. 1977. Status of six furbearer populations in the mountains of northern California. Unpublished report, USDA Forest Service, California Region, San Francisco, California, USA.

³ Gould, G. 1987. Job Final Report, Project W-65-R-4. Unpublished report, California Department of Fish and Game, Sacramento, California, USA.

⁴ Fowler, C.H. 1995. Techniques for detecting and monitoring martens and fishers in forest habitats of California. M.S. Thesis, Humboldt State University, Arcata, California, USA.

⁵ Zielinski, W.J. and T.E. Kucera, editors. 1995. American marten, fisher, lynx, and wolverine: survey methods for their detection. USDA Forest Service General Technical Report PSW-GTR-157.

American marten and wolverine, *Gulo gulo*, using standardized detection techniques. The incentive to conduct these surveys has increased due to two recent petitions to list the fisher under the Endangered Species Act^{6,7} and the uncertain status of other forest carnivores in the western United States (Kucera and Zielinski 1995). Our objectives are to describe the current distribution of the fisher in California based on these recent surveys and to document the feasibility and value of such efforts for the management of rare or secretive carnivores.

METHODS

We compiled the results of surveys that used baited track-plates (Barrett 1983, Fowler and Golightly⁸ 1993); line-triggered cameras (Jones and Raphael⁹ 1993); and remote, 35-mm cameras (Kucera and Barrett 1993a) in our efforts to detect evidence of fishers in California. These techniques produce either a track or a photograph from a known location. A few recent records of road-killed animals also were included, but only at locations where there were few surveys or where surveys had not otherwise documented the presence of fishers.

We summarize data from several types of surveys. Most (n = 221 surveys) were efforts by federal, state, or private biologists to determine the presence of fishers in an area where habitat alteration, such as a timber sale or recreational development, was planned. We also included data from regional surveys (n = 15 surveys), often conducted as the first phase of a more intensive research project, that were conducted to understand fisher distribution across one or several watersheds. Finally, we summarized data from a statewide survey (n = 84 stations) to detect rare carnivores, particularly wolverines. Many of the local efforts were conducted according to the USDA Forest Service Region 5 protocol (Zielinski¹⁰ 1992) in which baited track-plate stations (usually 12-24) are placed at 0.8-km intervals along roads in a proposed timber sale area. Some of these surveys were conducted with the goal of detecting martens, and thus may have been at elevations and in habitats where fishers were less common (Schempf and White² 1977, Buskirk and Powell 1994). Most regional surveys included considerably more stations than the local surveys (usually >50) and stations were distributed as either a grid or along roads across multiple watersheds. In the statewide survey, individual 35-mm cameras were

⁶ Central Sierra Audubon Society, North San Juan, California, in litt. 1990.

⁷ Biodiversity Legal Foundation, Boulder, Colorado, in litt. 1994.

⁸ Fowler, C. and R.T. Golightly. 1993. Fisher and marten survey techniques on the Tahoe National Forest. Final Report, Agreement No. PSW-90-0034CA, Humboldt State University and USDA Forest Service.

⁹ Jones, L.L.C. and M.G. Raphael. 1993. Inexpensive camera systems for detecting martens, fishers, and other animals: guidelines for use and standardization. USDA Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-306.

¹⁰ Zielinski, W.J. 1992. A survey protocol to monitor forest carnivores in proposed management activity areas. Unpublished report, USDA Forest Service, Pacific Southwest Forest and Range Experimental Station, Arcata, California, USA.

located in areas of historic or recent wolverine sightings specifically to detect this species (Kucera and Barrett 1993b). All types of surveys were mapped as a single point regardless of the number of stations in the survey, with the exception of those conducted by the Sierra Pilot Project in Nevada County. In this study, a 35-mm camera was placed at each of 150 grid intersections (section corners) in a 800-km² area.

All work was conducted from October 1989 to March 1995. The first two types of survey were conducted most often during the snow-free seasons, the third type primarily during the winter. Surveys occurred through much of the historic range of the fisher in California, but some areas were surveyed more intensively than others due to variation in how important land managers considered the need for information. All tracks and photographs were verified by one of the authors. Tracks of a size that could be confused with those of martens were distinguished using a discriminant function (Zielinski and Truex 1995). Details on the specific survey locations, detection techniques, and results are on file at the Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, California, and at the Department of Environmental Science, Policy, and Management at the University of California, Berkeley, California.

RESULTS

We report data from 510 survey sites, ranging from Del Norte, Humboldt, and Siskiyou counties in the north through the southern Cascades and Sierra Nevada to northern Kern County (Figs. 1 and 2). Ninety surveys detected a fisher at least once; most detections were in the northwest (northern Coast Range and Klamath Mountains) and on the west slope in the southern Sierra Nevada. No verifiable evidence of fishers was collected in the area from northeastern Shasta County south to Yosemite National Park, a linear distance of about 420 km, even though 66 track-plate surveys (each with multiple stations) and 184 35-mm camera stations (150 of which were used together in the Sierra Pilot Study) were deployed in this area.

DISCUSSION

Currently the fisher appears to occur in two areas of California; it is widely distributed in the northwest (northern Coast Range and Klamath Mountains) and has a restricted distribution in the southern Sierra Nevada. Although there have been occasional, unverified, sightings of fishers between Mt. Shasta and Yosemite National Park (E. Burkett, CDFG, pers. comm.), a considerable number of surveys in this region, using methods that readily detect fishers when they are present, have failed to detect them. This is not likely due to surveys being conducted at elevations above typical fisher habitat; mean elevation of the track-plate surveys in this region ($n = 46$) was 1650 m, similar to the mean elevation of fisher sightings reported by Schempf and White² (1977) for the northern Sierra Nevada. Despite our efforts to detect fishers, we have no quantitative measure of the probability that negative

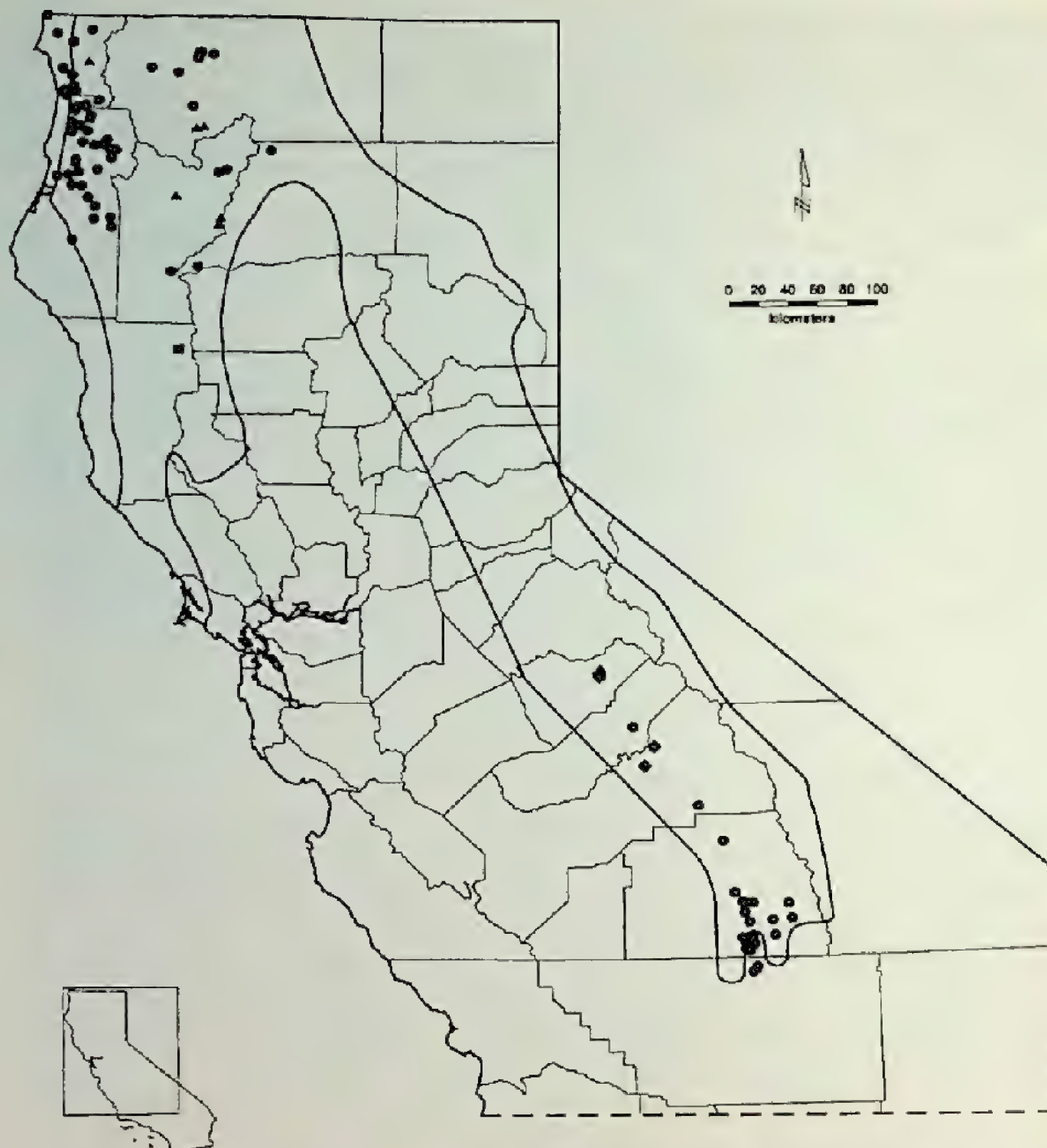


Figure 1. Locations in northern and central California where fishers *were detected*, 1989-1994. Circles indicate locations of surveys with multiple track-plate or line-triggered camera stations. Triangles indicate locations of individual 35-mm camera stations. Diamonds are locations of road-killed fishers, noted only for areas in the Sierra Nevada north of Sequoia National Forest. Yosemite National Park, in Mariposa County, is the site of two roadkills and two photographs, the symbols for which overlap considerably. The one solid square in Mendocino County is the location of two fisher captures, 3 months apart, in leg-hold traps set for other species. The bold irregular lines enclose the limits of historic fisher distribution as described by Grinnell et al. (1937). Outlines of counties also are shown.

results in a survey mean, in fact, that no fishers occur in a particular area. Most marked martens or fishers are readily detected at camera stations that are placed



Figure 2. Locations in northern and central California where fishers *were not detected*, 1989-1994. Circles indicate locations of surveys with multiple track-plate or line-triggered camera stations. Triangles indicate locations of individual 35-mm camera stations. The large, open rectangle includes the Sierra Pilot Project study area where a 35-mm camera was placed at each of 150 section corners throughout the 800-km² area. The bold irregular lines enclose the limits of historic fisher distribution as described by Grinnell et al. (1937). Outlines of counties also are shown.

within their home range (Jones and Raphael¹¹ 1990, Seglund and Golightly¹² 1993,

¹¹ Jones, L.L.C. and M.G. Raphael. 1990. Ecology and management of marten in fragmented habitats of the Pacific Northwest. Progress report, USDA Forest Service, Olympia, Washington, USA.

¹² Seglund, A. and R.T. Golightly. 1993. Fisher survey techniques on the Shasta-Trinity National Forest. Progress report, Humboldt State University and USDA Forest Service, Pacific Southwest Research Station, Arcata, California, USA.

Fowler⁴ 1995). This strongly suggests that the absence of fisher detections in the northern and central Sierra Nevada and in the southern Cascades is because they do not occur in the areas surveyed.

Grinnell et al. (1937:215) described the fisher as occurring "...south from Mt. Shasta and Lassen Peak *throughout* the main Sierra Nevada...." (italics added). Dixon (1925) concluded that the California fisher population was dangerously close to extinction and proposed that measures be taken to protect the species; in 1946 trapping for fishers was prohibited. Schempf and White² (1977) summarized fisher sightings in California through 1974 and indicated that the fisher was still at very low density in the northern Sierra Nevada. Gould³ (1987) suggested that, based on lack of sightings in the Sierra Nevada, the fisher be listed as threatened or endangered in the state. These reports, together with the absence of recent detections in the southern Cascades and northern Sierra Nevada reported here, suggest that the fisher population in this region has declined since the early 1900s. We hasten to add, however, that none of the methods used to describe distribution are suitable indices of abundance and that differences in the type and quality of data available over the 60-yr period make interpretation of distributional changes difficult.

Elsewhere in California, fisher detections occurred consistent with previous reports of fisher distribution. Detections were common in the Coast Range in Del Norte and Humboldt counties (several occurring within 7 km of the ocean), the Klamath Mountains, and as far east as near Mt. Shasta. Detections also were common in Sequoia National Forest, but decreased in frequency north to Yosemite National Park. In Yosemite, two road-killed fishers were collected in 1993 and 1994 and, after several years of effort, fishers were photographed at two baited camera stations (L. Chow, National Biological Service, pers. comm.). Fishers were detected at track-plates only once in the Sierra National Forest, where two road-killed fishers were recovered during 1991-94 (Fig. 1). In contrast, the majority of surveys farther south in the Sequoia National Forest detected fishers and road-killed fishers are relatively common there (S. Anderson, USDA Forest Service, pers. comm.).

A few surveys have been conducted in the Sierra Nevada since our maps were made. These include a regional track-plate survey in the Kings River Ranger District, Sierra National Forest, Fresno County, that detected fishers (R. Golightly, pers. comm.) and another regional track-plate survey in Tuolumne County that did not (D. Applebee, Sierra Pacific Industries, pers. comm.). Neither of these results appreciably change the mapped distribution.

Several areas of the historic distribution of fisher were inadequately surveyed. No surveys were conducted in southern Humboldt, Mendocino, or northern Lake counties where Grinnell et al. (1937) reported fishers trapped between 1919-1924. The accidental captures of two fishers in leg-hold traps in northern Mendocino County during the winter of 1994-1995 (C. Furrer, Mendocino National Forest, pers. comm.) indicate that surveys in Mendocino and Lake counties are necessary to define the southern boundary of the Coast Range population. Western Nevada, Placer, and El Dorado counties, and much of the eastern slope of the Sierra Nevada, also were poorly sampled. We strongly encourage increased survey effort in these

regions of California, as well as in southern Oregon to define the northern boundary of the northwestern California population.

In the late 20th century, the fisher appears to be distributed over a much smaller area in California than described in the early 1900s. Furthermore, its once continuous distribution is now apparently fragmented into two areas separated by a distance that greatly exceeds reported fisher dispersal ability (Arthur et al. 1993). Although the fisher always has occurred in the southern Sierra Nevada, the apparent current isolation renders this population vulnerable to catastrophic events in the short term and, possibly, inbreeding depression in the long term. This population is crucial to the restoration of the fisher in California because it is the one most likely to recolonize the remainder of the Sierra Nevada. Moreover, it is a likely source for transplants should reintroduction to the central and northern Sierra Nevada be considered. Although research on the habitat associations of fisher elsewhere in California may help explain why the fisher is uncommon in the northern and central Sierra Nevada, studies of remnant populations are an insufficient conservation strategy. It is more important that forests in the Sierra Nevada and southern Cascades be managed to encourage the natural dispersal of fishers into the area we currently believe is unoccupied.

We emphasize that the data reported here are based on verified tracks or photographs of fishers; they do not include reports of sightings. Sighting data need to be treated cautiously because they are impossible to verify, although reliability indices can be developed (Aubry and Houston 1992; E. Burkett, pers. comm.). We recommend that detection surveys using either track-plates or cameras be conducted at sites where fishers and other uncommon forest carnivores are reportedly observed and that standardized methods of these types be used during future efforts to assess the distribution of such species. Visual observations that are screened for reliability should be used to augment, not substitute for, surveys using cameras or track-plates.

ACKNOWLEDGMENTS

This work was supported by the Pacific Southwest Research Station and Region 5 of the USDA Forest Service (USFS); the CDFG; the California Department of Forestry and Fire Protection; the University of California, Berkeley Agricultural Experiment Station (Project 5410MS); Pacific Gas and Electric Company; the USDI Bureau of Land Management; and the Nature Conservancy. R. Schlorff and E. Burkett of CDFG and D. MacFarlane of USFS were particularly helpful. We thank C. Ogan, R. Truex, K. Busse and I. Timossi for assistance in data management. W. Krohn and M. White reviewed early drafts of this paper. S. A. Laymon and others from the Kern River Research Center provided data from work in the Sierra and Sequoia National Forests, R. Golightly provided data from work in northern California, L. Chow contributed data from Yosemite National Park, and D. Bise summarized work in several state forests. We also thank a number of biologists that work for private timber companies for releasing information on the location of their surveys, in particular R. Klug and L. Diller of Simpson Timber Company. Finally, we recognize

and National Park Service biologists who have generously cooperated by conducting the surveys and submitting their results to us.

LITERATURE CITED

- Arthur, S.M., T.F. Paragi, and W.B. Krohn. 1993. Dispersal of juvenile fishers in Maine. *Journal of Wildlife Management* 57:868-874.
- Aubry, K.B. and D.B. Houston. 1992. Distribution and status of the fisher (*Martes pennanti*) in Washington. *Northwest Naturalist* 73:69-79.
- Barrett, R.H. 1983. Smoked aluminum track plots for determining furbearer distribution and abundance. *California Fish and Game* 69:188-190.
- Buskirk, S.W. and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pages 283-296 *in*: S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Dixon, D.G. 1925. A closed season needed for fisher, marten and wolverine. *California Fish and Game* 11:23-25.
- Gibilisco, C.J. 1994. Distributional dynamics of modern *Martes* in North America. Pages 59-71 *in*: S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Graham, R.W. and M.A. Graham. 1994. The late quaternary distribution of *Martes* in North America. Pages 26-58 *in*: S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Grinnell, J., J.S. Dixon, and J. Linsdale. 1937. *Fur-bearing mammals of California*, volume 1. University of California Press, Berkeley, California, USA.
- Hagmeier, E.M. 1956. Distribution of marten and fisher in North America. *Canadian Field-Naturalist* 70:149-168.
- Kucera, T.E. and R.H. Barrett. 1993a. The Trailmaster camera system for detecting wildlife. *Wildlife Society Bulletin* 21:505-508.
- Kucera, T.E. and R.H. Barrett. 1993b. The California Cooperative Wolverine Survey. *Transactions of the Western Section of the Wildlife Society* 28:49-53.
- Kucera, T.E. and W.J. Zielinski. 1995. The case of forest carnivores: small packages, big worries. *Endangered Species Update* 12:1-7.
- Powell, R.A. 1993. *The fisher: life history, ecology, and behavior*, second edition. University of Minnesota Press, Minneapolis, Minnesota, USA.
- Raphael, M.G. 1994. Techniques for monitoring populations of fishers and American martens. Pages 224-240 *in*: S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Yocom, C.F. and M.T. McCollum. 1973. Status of the fisher in northern California, Oregon, and Washington. *California Fish and Game* 59:305-309.
- Zielinski, W.J. and R.L. Truex. 1995. Distinguishing tracks of marten and fisher at track-plate stations. *Journal of Wildlife Management* 59:571-579.

Received: 15 June 1995

Accepted: 1 October 1995

ACCURACY OF CEMENTUM AGE ASSIGNMENTS FOR BLACK BEARS

JEFFREY A. KEAY¹

National Park Service

Yosemite National Park, California 95389

The accuracy of assigned black bear, *Ursus americanus*, ages based on cementum annuli counts of teeth was assessed. Ages assigned by two independent, experienced observers were statistically different, but biologically unimportant for most management purposes. Discrepancies between the assigned ages of two premolars extracted during the same year increased with animal age. Assigned ages were accurate for animals less than 6 yr old, but tended to underestimate true age as animal age increased. Observed discrepancies could be important when reporting an early age of first reproduction, when calculating age specific reproduction or survival, or when managing small populations.

INTRODUCTION

Although the cementum annuli technique has been widely used to assign ages in black bears, *Ursus americanus*, (Marks and Erickson 1966, Sauer et al. 1966, Stoneberg and Jonkel 1966, Willey 1974, Rogers 1978, O'Pezio 1980) accuracy and precision of the method have not been critically examined. Cementum counts of known-age samples, especially from older-age bears, are rare and, despite the development of criteria to promote consistency (Rogers 1978, O'Pezio 1980, Rice 1980), the method remains subjective (O'Pezio 1980).

The pattern and clarity of annuli affect the accuracy of cementum counts and may be related to sex, reproductive history (Rogers 1975 a, b, cited by O'Pezio 1980; Rogers 1978), age (Sauer et al. 1966, Rogers 1978, Hildebrandt 1979, O'Pezio 1980), health of teeth and gums (O'Pezio 1980), and length of growing season (Rogers 1978).

Lacking known-age samples, biologists implicitly assume that age assignments are unbiased or that positive and negative biases offset one another for large sample sizes. If biases in age assignments are consistently positive or negative, however, subsequent interpretations of the demographics and dynamics of a population may be erroneous. If such biases can be identified, age assignments may be adjusted to minimize error and misinterpretations.

In this paper, I tested the hypotheses that i) cementum age assignments did not differ between two experienced observers (observer differences), ii) there was no difference between assigned ages from first premolars collected from the same bear during the same year (consistency of counts), and iii) error in assigned ages did not vary with the sex or age of the bear (bias).

¹ Current address: National Biological Service, c/o Denali National Park and Preserve, P.O. Box 9, Denali Park, Alaska 99755.

METHODS

First premolars were extracted from nuisance black bears live-captured from spring through fall for management purposes in Yosemite National Park, California (Keay² 1990). Teeth were frozen (-10°C) until sent to a commercial laboratory for sectioning. Multiple teeth from a single bear were labeled so that technicians would not know their origin. Sex and date of collection were provided for each sample. Cementum counts were made from 14- μ mid-sagittal sections stained with giemsa blood stain (Stone et al. 1975) and permanently mounted on glass slides. Age assignments (to the nearest year) were made by a single technician at the commercial laboratory who also assigned one of three certainty codes. Certainty code A meant the result was nearly certain, with expected error of 0 for bears <8 yr old, ± 1 yr for bears 8 to 15 yr, and ± 2 yr for bears over 15 yr. Error code B meant some error was possible, with 1 yr added to each code A error estimate. Error code C meant error was likely, with 1 yr added to the code B error estimates for each age class.

Observer differences were analyzed by comparing age assignments from the commercial laboratory with those of an experienced technician with the Minnesota Department of Natural Resources. Only age assignments from the commercial laboratory were used in other analyses.

Sex- and age-related bias in cementum age assignments were evaluated from differences between known age (bears captured as cubs or yearlings) and cementum-assigned age, and between two cementum-assigned ages for teeth extracted from the same bear at a known interval of ≥ 1 yr. If bias does not increase with age, the length of time between multiple tooth collections would not affect the results. Therefore, the first and last teeth collected were used. The assigned age from the first collected tooth, plus the known time interval between tooth collections, was subtracted from the assigned age of the second sample to provide a difference in age assignments.

Sex and age subgroups were evaluated for differences in age assignments using analysis of variance (ANOVA) of ranked counts (Conover and Iman 1981). Subgroups were pooled when no differences ($P > 0.05$) were found. Five-yr subgroups were biologically meaningful for this population because maximum cub production consistently occurred at age 6 and decreased cub production was observed after age 15 (Keay² 1990). The Wilcoxon Signed Ranks Test was used for multiple comparisons of pooled subgroups to test the hypotheses of no difference between assignments made by two observers and between cementum assignments from teeth extracted during different years.

Linear regression was used to test for a significant relationship and bias between known age and assigned age. Correlation analysis provided a measure of the amount of correlation between assigned ages of teeth extracted at known intervals. Linear regression was not appropriate to test for differences between observers or between

² Keay, J.A. 1990. Black bear population dynamics in Yosemite National Park. Ph.D. Dissertation, University of Idaho, Moscow, Idaho, USA.

multiple teeth because the independent variables in those tests were known to have error.

Age assignments from premolars collected from the same bear during the same year were compared to test for consistency of cementum counts between different teeth. Mantel-Haenszel and Pearson Chi-square Tests (Wilkinson 1988) were used to compare differences in the two estimates. The Wilcoxon Signed Ranks Test was not appropriate for this procedure because the ordering of pairs, and hence the sign, was arbitrary and only the absolute value of the difference was meaningful.

Any differences in age assignments from the actual age would be important to detect. Consequently, the rejection criterion for the principal hypotheses was $P < 0.10$. Statistical calculations were done on a desk-top computer using SYSTAT (Wilkinson 1988).

RESULTS

Ages were assigned to 256 black bears from cementum annuli counts. Multiple samples were available for 85 bears. Not all samples were used in all analyses.

Observer Differences

Differences in age assignment between two observers were evaluated from 89 samples which ranged from 0 to 16 yr for females ($n = 35$) and from 1 to 12 yr for males ($n = 54$) (Table 1). Age assignments by independent observers were identical for 69% of female and 74% of male samples. The magnitude of the difference varied from 0 to 1 for females < 6 yr old, 0 to 3 for older females, 0 to 2 for males < 6 yr, and 0 to 4 for older males. The level of agreement between observers was related to the distinctness of annuli in tooth sections. Identical age assignments were made for 85% of the samples with certainty code A ($n = 46$), 61% with code B ($n = 36$), and 42% with code C ($n = 7$).

The average difference between age assignments by observers differed between sexes ($P = 0.060$) and age groups ($P = 0.046$) (Table 2). One observer underestimated

Table 1. Percent of black bear premolar age assignments from two observers that differed by 0 to 4 years, Yosemite National Park, California, 1975-1988.

Sex/age group in years	Age difference in years				Sample size
	0	1	2	≥ 2	
Females:					
0 to 5	82	18	0	0	22
6 to 16	46	38	8	8	13
Males:					
0 to 5	76	19	5	0	42
6 to 12	67	8	17	8	12

Table 2. Mean difference in age assignments of black bears from cementum analysis by two independent observers. The sign of the mean signifies that one observer gave either higher or lower age assignments than the other.

Sex	Age group in years					
	0-5			6-16		
	Mean	SD	Sample size	Mean	SD	Sample size
Female	-0.18 ^a	0.40	22	0.00	1.23	13
Male	-0.05	0.62	42	0.75 ^a	1.29	12

^astatistically significant ($P < 0.10$)

the age of females <age 6 ($P = 0.046$, $n = 22$) compared to the other, yet overestimated the age of males ≥ 6 yr old ($P = 0.066$, $n = 12$).

Consistency Between Tooth Samples

Assigned ages for 60 samples of paired premolars, extracted from individual bears in the same year, ranged from 1 to 31 yr for females ($n = 29$) and 0 to 20 yr for males ($n = 31$). Of these, 30 were <6 yr of age, 18 were 6-10 yr old, six were 11-15, four were 16-20, and two were >20 yr of age. The difference between age assignments for paired premolars was 0 yr for 40 samples, 1 yr for 11 samples, 2 yr for three samples, 4 yr for one sample, 5 yr for one sample, and 6 yr for three samples (Table 3). One bear >age 20 had paired estimates that differed by 16 yr.

Differences in age assignments for paired teeth were not related to sex ($P = 0.382$) but were related to age ($P = 0.006$). Six bears >age 10 had cementum counts that varied from 4 to 16 yr. Age assignments from the second tooth collected from these bears ranged from 12 to 31 yr and in all cases had certainty codes of B or C. The greatest difference in age assignments occurred in the oldest bears.

Multiple tooth samples were available for three known-age bears >6 yr old. For one of the bears, both teeth were extracted at age 6; the counts were consistent but underestimated true age by 1 yr. For another bear, two teeth were collected at age 9, but counts differed by 1 yr and they underestimated true age by 1 and 2 yr. For the third bear, from which teeth were collected at 2 and 7 yr, age assignments differed by 2 yr, and the assigned ages underestimated known age by 1 and 3 yr, respectively.

Bias

Known-Age Bears

Cementum age assignments were made for 45 known-age bears, 20 caught as cubs, and 25 caught as yearlings. Accuracy of assigned ages for these two groups did not differ ($P > 0.05$), so the data were pooled. Age assignments differed from known

Table 3. Percentage of assigned ages of paired black bear premolars, extracted during the same year, that differed by 0 to 16 years, Yosemite National Park, California, 1975-1988.

Age group in years	Age difference in years				Sample size
	0	1	2	≥3	
0 to 5	83	13	3	0	30
6 to 10	67	22	11	0	18
> 10	25	25	0	50	12

age by 1 yr for 19% (n = 26) of teeth from bears <8 yr old and given accuracy code A. Four of the five errors underestimated known age. Age assignments also differed by 1 yr for 31% (n = 13) of known-age teeth from bears <age 8 given accuracy code B. Three of the four errors overestimated known age. Sample sizes were too small to evaluate other age or code categories.

Ages of the known samples ranged from 1 to 9 yr for females and 0 to 12 yr for males. However, most were young: 11 of 24 females were yearlings, 10 were 2-5 yr and three were 6-9 yr. All males, except one 12-yr-old, were age 0-2. Differences between known and assigned age varied from -1 to +1 for bears of both sexes <6 yr old. Differences varied from -3 to -1 for three females known to be age 6-9. The cementum-age assignment for the 12-yr-old male was correct.

Cementum-assigned age was significantly related to known age (*P* = 0.000) (Fig. 1), but not to sex (*P* = 0.629). The regression equation was:

Assigned Age = 0.237 + 0.86 (Known Age).

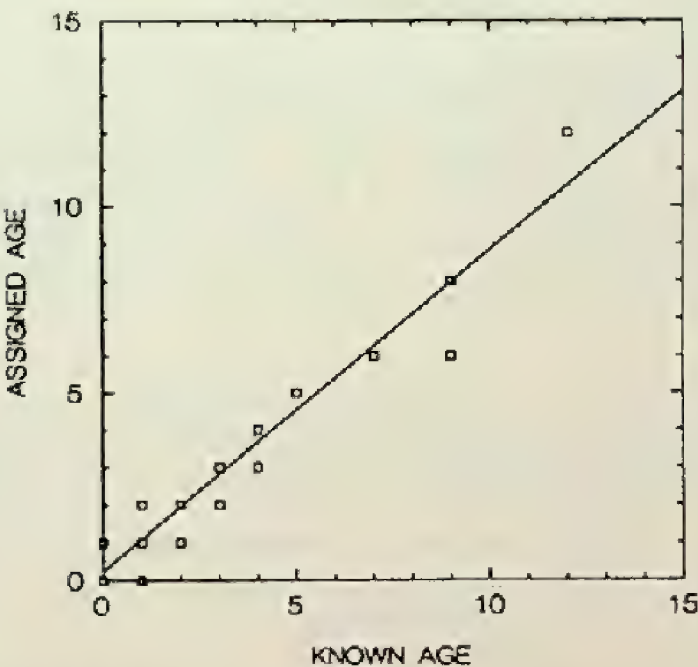


Figure 1. Relationship between assigned ages from cementum annuli counts and known ages of black bears from Yosemite National Park, California, 1975-1988. $Y = 0.237 + 0.86X$, $r^2 = 0.937$. Some plotted data points represent more than one observation.

Both slope and intercept were significantly different from 0 ($P = 0.048$ and 0.000 , respectively) and the slope was different from 1.0 ($P = 0.000$) indicating a significant bias toward underestimating true age as black bear age increased.

Known Interval Sample

Premolars extracted in different years were available from 33 black bears whose assigned ages ranged from 2 to 20 yr (Table 4). Intervals between the collection of samples ranged from 1 yr ($n = 19$) to 9 yr ($n = 1$); the remaining observations were evenly distributed between these intervals.

Age assignments between the pairs of teeth differed significantly ($P = 0.014$), with the last tooth collected suggesting a younger age than the first tooth. The difference was not due to the bear's sex ($P = 0.919$) but was related to age ($P = 0.030$). Assigned age of the second tooth was significantly correlated with the assigned age of the first tooth ($P = 0.001$, Fig. 2). The best-fitting line was:

$$\text{Assigned Age 2} = 0.276 + 0.868 (\text{Assigned Age 1} + \text{Extraction Interval}).$$

The relationship between the magnitude of difference in age assignments and the interval between extractions was not significant ($P = 0.210$). In older bears, all observed differences (from -4 yr to +2 yr) occurred between teeth extracted only 1 yr apart. The two observations of 4-yr differences, from a 1-yr collection interval, were from bears whose assigned ages (from the first premolar collected) were 10 and 14 yr. Two pairs of teeth collected at 6- and 7-yr intervals recorded no difference in age assignment.

DISCUSSION

Cementum age assignments for Yosemite black bears were very closely correlated with true age, especially for young bears. The high correlation and consistent estimates suggest cementum annuli serve as good estimators of black bear age. Discrepancies between cementum assigned ages for both multiple teeth and known age teeth indicated a slight bias toward underestimating true age that increased with

Table 4. Percentage of assigned ages from black bear premolars extracted at known intervals that differed by +2 to -4 years, Yosemite National Park, California, 1975-1988.

Age group in years	Age difference in years							Sample size
	2	1	0	-1	-2	-3	-4	
0 to 5	0	7	47	33	7	7	0	15
6 to 10	18	9	36	9	0	18	9	11
> 10	14	0	14	14	14	29	14	7

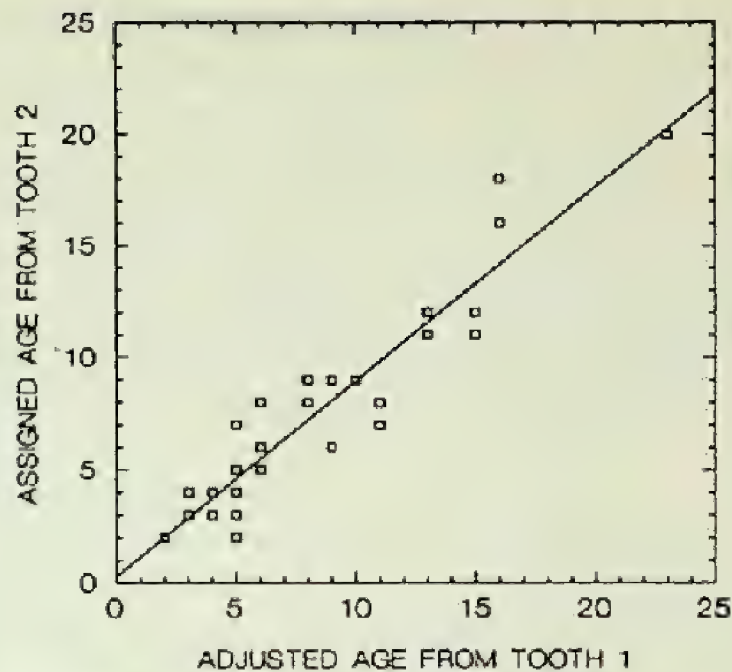


Figure 2. Relationship between assigned ages from cementum annuli counts of two first premolars obtained from individual black bears in different years, Yosemite National Park, California. 1975-1988. $Y = 0.276 + 0.868X$, $r^2 = 0.891$. (Note: The assigned age from the first tooth collected was adjusted for comparison by adding the interval between extractions in years. Some plotted data points represent more than one observation.)

black bear age. For conservation of large populations with low harvest the amount of bias detected in this study is of little importance to management. Under intensive harvest strategies when survival rates are based on age distribution, or conservation of threatened populations, a bias in age assignments could have a substantial impact on sustained yield or recovery potential.

The similarity between the regression coefficients for the known interval and known age data from my study may not be fortuitous. One would expect the equations to be very similar because of the accuracy of age assignments for younger bears, which were well represented in both samples. If biases are detected, they may be adjusted by inverse prediction (Zar 1974). For example, to obtain the best estimate of a bear's age using data from this study, invert the least squares equation as follows:

$$\text{Predicted Age} = (\text{Assigned Age} - 0.276) / 0.868.$$

Other studies documented accurate age assignments for young bears (Marks and Erickson 1966, Sauer et al. 1966, Stoneberg and Jonkel 1966, McLaughlin et al. 1990). Differences in age assignment from multiple teeth from Maine black bears also increased with bear age (McLaughlin et al. 1990). As here, tooth samples collected later in a bear's life suggested a more recent birth date, and hence, younger age.

The two technicians used in this study felt that tooth cementum characteristics for black bears in California were different from those of many other bear populations, and more difficult to age. The dark cementum band patterns were irregular, with non-annual bands being numerous and widely spaced from annual ones and thus

more easily mistaken as annual. Annual bands were often indistinct at many points of the section. Mounting multiple sections from each tooth may assist in annual band identification.

Differences in age assignments between observers, as detected in this study, are not new. Cumming and Evans (1978) expressed concern about the value of cementum counts in assigning ages to moose because of differing observer results. McLaughlin et al. (1990) documented that experienced technicians assigned younger ages to black bears from cementum annuli counts than did inexperienced technicians. This study demonstrated a difference in age assignment by two highly experienced technicians.

How to minimize bias depends on whether it is due to the structural characteristics of the tooth or the observer's ability to detect them. Use of multiple tooth sections and multiple observers working closely together apparently produced more accurate age assignments for polar bears than from a single observer (W. Calvert, Canadian Wildlife Service, Edmonton, Alberta, pers. comm.)

In the absence of multiple, highly-skilled technicians, the use of a single observer with standardized aging criteria would provide more consistent and readily correctable results. Use of multiple observers, unless they consistently worked together, would add confusion without an evaluation of which assigned age was more accurate. Multiple teeth may be required to more accurately assign ages of older bears. The problem that remains, however, is to assign an age to an individual bear when multiple cementum counts disagree. These data suggest the age assignment made when the bear was youngest is probably least biased and should be used. When multiple samples are obtained during the same year, the oldest assigned age is probably least biased. Because overestimates do occur, however, this approach provides no assurance of accuracy. The mean or median, on the other hand, probably would be biased and underestimate true age, but less than a single tooth. Unfortunately, even consistency in cementum age assignments from multiple tooth samples does not insure accuracy. Incorporating observed tooth wear, body size, and condition of the animal with cementum counts will likely provide the best age assignments.

ACKNOWLEDGMENTS

I thank E. Garton and K. Steinhorst for statistical advice and review of an earlier draft of this manuscript. G. Matson of Matson's Laboratory and P. Coy from the Minnesota Department of Natural Resources are greatly appreciated for assigning ages and providing technical assistance. D. Koch and D. Graber shared cementum age data. J. vanWagtendonk, S. Thompson, J. Peek, E. Loft, G. Matson, M. Taylor, D. Koch, R. Stafford, and five anonymous reviewers provided valuable comments on the manuscript. This research was supported by the National Park Service and the Yosemite Fund.

LITERATURE CITED

- Conover, W.J. and R.L. Iman. 1981. Rank transformation as a bridge between parametric and nonparametric statistics. *The American Statistician* 35:124-129.
- Cumming, H.G. and R. Evans. 1978. Repeatability of incisor cementum age determinations for moose. *Proceedings of the North American Moose Conference Workshop* 14:68-88.
- Hildebrandt, T.D. 1979. Age determination in Michigan black bear by means of cementum annuli. Pages 52-60 *in*: D. Burk, editor. *The black bear in modern North America*. Boone and Crockett Club and The Amwell Press, Clinton, New Jersey, USA.
- Marks, S.A. and A.W. Erickson. 1966. Age determination in the black bear. *Journal of Wildlife Management* 30:389-410.
- McLaughlin, C.R., G.J. Matula, R.A. Cross, W.H. Halteman, M.A. Caron, and K.I. Morris. 1990. Precision and accuracy of estimating age of Maine black bears by cementum annuli. *International Conference on Bear Research and Management* 8:415-419.
- O'Pezio, J. 1980. Interpretation of cementum annuli for age assignment of the black bears. Pages 156-166 *in*: *Proceedings of the 5th Eastern Black Bear Workshop*, Wrightsville Beach, North Carolina, USA.
- Rice, L.A. 1980. Influences of irregular dental cementum layers on aging deer incisors. *Journal of Wildlife Management* 44:266-268.
- Rogers, L.L. 1975a. The use of dental annuli as an index to reproductive success. Page 62 *in*: *Abstracts of technical papers presented at the 55th annual meeting of the American Society of Mammalogy*, University of Montana, Missoula, Montana, USA.
- Rogers, L.L. 1975b. Black bears of the Lake Superior Region. *North Land* 3:1-6.
- Rogers, L.L. 1978. Interpretation of cementum annuli in first premolars of bears. Pages 102-112 *in*: *Proceedings of the 4th Eastern Black Bear Workshop*, Greenville, Maine, USA.
- Sauer, P.R., S. Free, and S. Browne. 1966. Age determination in black bears from canine tooth sections. *New York Fish and Game Journal* 13:125-139.
- Stone, W.B., A.S. Clauson, D.E. Slingerlands, and B.L. Weber. 1975. Use of Romanowsky stains to prepare tooth sections for aging mammals. *New York Fish and Game Journal* 22:156-158.
- Stoneberg, R.P. and C.J. Jonkel. 1966. Age determination of black bears by cementum layers. *Journal of Wildlife Management* 30:411-414.
- Wilkinson, L. 1988. SYSTAT: The system for statistics. SYSTAT, Inc., Evanston, Illinois, USA.
- Willey, C.H. 1974. Aging black bears from first premolar tooth sections. *Journal of Wildlife Management* 38:97-100.
- Zar, J.H. 1974. *Biostatistical analysis*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, USA.

Received: 19 January 1995

Accepted: 23 June 1995

BLACK BEAR REPRODUCTIVE RATES IN YOSEMITE NATIONAL PARK

JEFFREY A. KEAY¹

National Park Service

Yosemite National Park, California 95389

Reproductive rates of nuisance black bears, *Ursus americanus*, in Yosemite National Park were examined from 1974 through 1988, concurrent with an effort by the National Park Service to reduce the availability of human-provided foods. Summer litter size averaged 1.6 cubs in the wilderness areas and was stable through the 15-yr study. Litter size in developed portions of the park declined from 2.0 cubs, among the highest reported for a western black bear population, to 1.3 cubs, the lowest reported. Age of first reproduction for females in developed areas was 4.1 yr. The proportion of females accompanied by summer litters averaged 0.33 in wilderness and 0.42 in developed areas. The estimated average interval between litters for females in developed areas was 2.1-2.4 yr. Overall reproductive rates did not differ between management areas and did not decline through the study period. Reproductive rate declined with increased adult female age. Reproductive parameters of females captured in wilderness were typical of a western black bear population. Reproductive parameters of females using developed areas appeared high throughout the study, suggesting that they had continued access to nutritious human food. The decline in litter size coincided with installation of bear-proof food storage lockers in developed campgrounds and may suggest the beginning of a reduction in nutrient availability.

INTRODUCTION

Black bears, *Ursus americanus*, in Yosemite National Park have used food (including garbage) provided intentionally and unintentionally by humans since the 1920s. This relationship between un hunted bears and humans over a period of 70 yr led to serious conflicts, including personal injury and property damage (Harms 1977, 1980; Keay and van Wagendonk 1983; Keay and Webb 1989). It also led to alterations in the natural behavior (Hastings and Gilbert 1987); foraging habits (Graber and White 1983); reproductive rates; physical size; distribution; and, presumably, abundance of bears in the park (Harms 1977, 1980; Graber² 1982).

¹ Current address: National Biological Service, c/o Denali National Park and Preserve, P.O. Box 9, Denali Park, Alaska 99755

² Graber, D.M. 1982. Ecology and management of black bears in Yosemite National Park. Cooperative Parks Studies Unit, Technical Report No. 5. University of California, Davis, California, USA.

In 1975, the National Park Service initiated an intensive Human-Bear Management Program in Yosemite (Harms 1977, 1980; USDI³ 1982; Keay and Webb 1989). The objectives of that program included the elimination of human-provided food and garbage accessible to bears.

The intensity with which each program element was implemented varied among management areas (Keay and Webb 1989). In developed areas the removal of artificial food sources began with closing open pit garbage dumps by 1971. Garbage cans and dumpsters were bear-proofed by 1975 and steel food storage lockers were installed in all but three front-country campgrounds from 1977 to 1988.

In wilderness, artificial food-source removal also began in the 1970s, with the installation of food suspension cables in heavily used areas. Food storage lockers were installed in one wilderness campground in 1979. Food storage poles were installed in selected sites in the mid-1980s. However, these steps were not successful in reducing human food availability in wilderness areas. The poor results are suggested by the lack of visitor compliance with approved food storage procedures (Cella and Keay^{4,5} 1979, 1980), lack of decline in the number of bear-caused property damage incidents, and continued bear access to human food (Keay and Webb 1989).

The purpose of my research was to evaluate the effect of the Yosemite Human-Bear Management Program on reproductive performance of the black bear population. Specifically, I tested the hypotheses that litter size, age at first reproduction, proportion of females with litters, and overall reproductive rate did not change with management efforts to reduce human food availability. I also tested the hypotheses that there was no change in litter size, proportion of females with litters, or reproductive rate with increasing age of adult female bears. I compared observed indicators of reproductive performance with those of other studies to evaluate how reproductive rates in Yosemite compared to the park goal of a natural population, uninfluenced by human activities.

STUDY AREA

Yosemite National Park occupies 308,000 ha on the west slope of the Sierra Nevada in central California. Elevation in the park ranges from 600 m on the western boundary to 4,000 m on the crest. The climate is Mediterranean with hot, dry summers and cool, moist winters. The roadless wilderness of the park covers 277,000 ha. Yosemite averaged over 2.7 million visitors/yr for the 15-yr period 1974-1988. Wilderness use averaged 62,244 visitors/yr.

Four major vegetation types occur in Yosemite National Park (Barbour and

³ USDI (U.S. Department of the Interior). 1982. Human/bear management plan. National Park Service, Yosemite National Park, California, USA.

⁴ Cella, W.B. and J.A. Keay. 1979. Annual bear management and incident report. National Park Service, Yosemite National Park, California, USA.

⁵ Cella, W.B. and J.A. Keay. 1980. Annual bear management and incident report. National Park Service, Yosemite National Park, California, USA.

Major 1977). (i) A limited amount of chaparral (7,000 ha), consisting of oaks, *Quercus* spp.; manzanita, *Arctostaphylos* spp.; and ceanothus, *Ceanothus* spp., exists at the lower elevations. (ii) The mixed conifer type occupies 65,000 ha between 1,300 m and 2,000 m. The most prevalent species in this type are ponderosa pine, *Pinus ponderosa*; sugar pine, *P. lambertiana*; incense cedar, *Calocedrus decurrens*; white fir, *Abies concolor*; and California black oak, *Q. kelloggii*. (iii) The 70,000-ha red fir, *A. magnifica*, type is found between the mixed conifer type and 2,700 m elevation. (iv) The lodgepole pine, *P. contorta*, subalpine type extends to 3,300 m and covers 122,000 ha of Yosemite. The remaining 44,000 ha are above timberline.

Historically, black bears inhabited the chaparral and mixed conifer types and were only rarely seen above 2,500 m (Grinnell and Storer 1924). In recent years, however, they have been commonly sighted at 3,100 m in the subalpine type. Property damage by bears has occurred throughout 75% of the park's wilderness, regardless of vegetation type (Keay and van Wagtendonk 1983), and in all of the developed areas (Keay and Webb 1989).

For purposes of my study, the park was divided into two management areas, developed and wilderness. The developed area included four of the five front-country districts and subdistricts (Fig. 1). The Valley District includes Yosemite Valley, which received 70% of visitor use. Wawona was not included because only six females were captured there. The wilderness area included all areas of the park >5 km from a public road.



Figure 1. Front-country districts and subdistricts, developments (hash-marked) and visitor access roads in Yosemite National Park, California. Wilderness areas are >5 km from a public road.

METHODS

Black bears were captured from April through November using culvert traps and Aldrich foot snares, or were chemically immobilized while ranging freely by using projectile syringes or jab-sticks. Bears that were habituated to humans or conditioned to human food were predisposed to capture because of capture techniques and locations of capture attempts; based on the number of individuals involved in nuisance activities, these bears were estimated to make up 60-80% of the population. Bears were immobilized with phencyclidine hydrochloride plus acepromazine; a mixture of ketamine hydrochloride and xylazine hydrochloride; or, for a few animals, etorphine hydrochloride. Each bear was marked with a metal cattle ear tag and lip-tattooed for identification. Bears were aged by cementum annuli counts from first premolars, which were adjusted for bias (Keay 1995). Age 1-3 bears were classified as subadults; older bears were classified as adults (Beecham 1980, LeCount 1982). Litter sizes were determined by the number of cubs observed with a female at the time of first capture.

Bears were assigned to either the developed or wilderness area based on the location of their first capture for that year. Consequently, bears using both developed and wilderness areas would be included in only one area for a given year. This approach was necessary to insure independence of observations by not including a female's litter twice in an analysis.

Capture data were tabulated annually to provide yearly estimates of reproductive parameters. Age at first reproduction was the mean age at which females were known to produce their first cubs. Annual reproductive rates were calculated as the total number of cubs observed divided by the total number of adult females captured for a given year.

Statistical analyses were done on a personal computer using SYSTAT (Wilkinson 1988). Chi-square analysis was used to assess capture vulnerability of bears captured several times by comparing the frequency with which females with cubs were captured, the frequency with which females without cubs were captured, and the frequency with which females were not captured in a given year. Expected values were 1/3 of the total count and assumed random capture probability and equal likelihood of each event. Chi-square was also used to compare the number of females with and without litters between management areas. Analysis of variance was used to compare litter size, age of first reproduction, and average annual reproductive rate between wilderness and developed areas and 5-yr groupings of the data. Trends in average proportion of females with litters, reproductive rate, mean litter size, and proportion of females with litters were evaluated with least-squares linear regression. In all tests, differences were considered significant for $P < 0.05$.

RESULTS

Fidelity of female bears to wilderness and developed areas (72% and 94%, respectively, Keay⁶ 1990) suggested minimal overlap in management area use. Only 3% of captured bears used both developed and wilderness areas during the same year. Including them in only one management unit/yr did not alter results.

Ninety-three different adult female black bears were captured 223 times over a 15-yr period. Developed areas and wilderness had 71% and 29% of the captures, respectively. Forty-seven percent of the captures occurred during the first 5 yr of the study. The remaining two 5-yr intervals had 31% and 22% of the captures.

The presence of litters and litter size was determined for 95% of lactating females captured in developed areas ($n = 138$) and 75% of wilderness area captures ($n = 40$).

Female black bears with cubs were not more vulnerable to capture than females without cubs ($P = 0.123$, $n = 158$). Adult female bears captured over at least a 3-yr period were captured 33.5% of the time with cubs, 39.9% without cubs, and were not captured in 26.6% of the years ($n = 158$ bear-yr, 31 bears).

Litter Size

Litter sizes in the wilderness area averaged 1.6 cubs ($n = 24$) and did not change through the study years ($P = 0.478$, $n = 24$, Table 1). Mean annual litter size declined in the developed area during the 15 yr of the management program ($P = 0.030$, $n = 68$). Litter size averaged 2.0 during the first 10 yr and 1.3 during the program's last 5 yr. Litter size did not differ between wilderness and developed areas ($P = 0.474$, $n = 92$).

Age at First Reproduction

The age of first reproduction increased for bears in developed areas ($P = 0.040$, $n = 12$) and averaged 3.0 the first 5 yr ($n = 3$), 4.5 the second 5 yr ($n = 4$) and 4.6 during the final 5 yr of the study ($n = 5$). The small sample of wilderness bears precluded calculation of age of first reproduction.

Proportion of Adult Females with Litters

An average of 33% of adult females using wilderness ($n = 64$) and 42% of those using developed areas ($n = 159$) were accompanied by litters each year. This difference was not statistically significant ($P = 0.197$, $n = 223$). During the 15 yr of the study, neither bears in wilderness areas ($P = 0.516$, $n = 64$) nor in developed areas ($P = 0.779$, $n = 159$) exhibited significant trends in the proportion of adult females with litters.

⁶ Keay, J.A. 1990. Black bear population dynamics in Yosemite National Park. Ph.D. Dissertation. University of Idaho, Moscow, Idaho, USA.

Table 1. Mean litter size, standard deviation, and sample size of black bears by management area for 5-year intervals, Yosemite National Park, California, 1974-1988.

<u>Management Area</u>	<u>1974-78</u>			<u>1979-83</u>			<u>1984-88</u>		
	<u>Mean</u>	<u>SD</u>	<u>Sample size</u>	<u>Mean</u>	<u>SD</u>	<u>Sample size</u>	<u>Mean</u>	<u>SD</u>	<u>Sample size</u>
Wilderness	1.71	0.756	7	1.67	0.500	9	1.50	0.535	8
Developed	1.95	0.815	38	2.00	0.767	18	1.31	0.480	13

Interval Between Litters

In developed areas of Yosemite, the average interval between litters was 2.1 yr ($SD = 0.243$, $n = 12$ bears, 29 litters). Samples were too small to calculate the interval between litters for wilderness areas.

Reproductive Rate

Annual reproductive rates did not differ between 5-yr intervals ($P = 0.659$, $n = 29$) or between wilderness and developed areas ($P = 0.241$, $n = 29$). Annual reproductive rates averaged 0.546 ($SD = 0.587$, $n = 14$ yr) and 0.786 ($SD = 0.452$, $n = 15$ yr) in the wilderness and developed areas, respectively.

Combined data showed a decline in black bear reproductive rate with increased female age (Fig. 2) from 6 to 23 yr ($P = 0.032$, $n = 16$ ages, 125 bear-yr). The regression equation was:

$$\text{Reproductive Rate} = 1.525 - 0.070 (\text{Age}).$$

The decrease in reproductive rate occurred primarily due to a decline in the percentage of females with litters as age increased ($P = 0.008$, $n = 18$ ages, 221 bear-yr). Only two litters were detected during 20 captures of 14 females aged 14-23 yr. Both litters were with 16-yr-olds. Mean litter size did not decline between 4 and 16 yr of age ($P = 0.198$, $n = 11$ ages, 61 litters).

DISCUSSION

Mean black bear litter sizes reported for western North America have varied from 1.32 to 1.96 (Rust 1946, Erickson and Nellor 1964, and Hatler⁷ 1967, cited by Bunnell and Tait 1981; Jonkel and Cowan 1971; Piekielek and Burton 1975; Lindzey and Meslow 1977; Beecham 1980; Reynolds and Beecham 1980; LeCount 1982). Mean litters sizes measured in eastern populations have been larger, ranging from 1.8 to 2.7 (Bunnell and Tait 1981, Rogers 1987). Captive bears and those whose diets were supplemented with human food had mean litter sizes of 3.0 in Minnesota

⁷ Hatler, D.F. 1967. Some aspects in the ecology of the black bear, *Ursus americanus*, in interior Alaska. M.S. Thesis, University of Alaska, College, Alaska, USA.

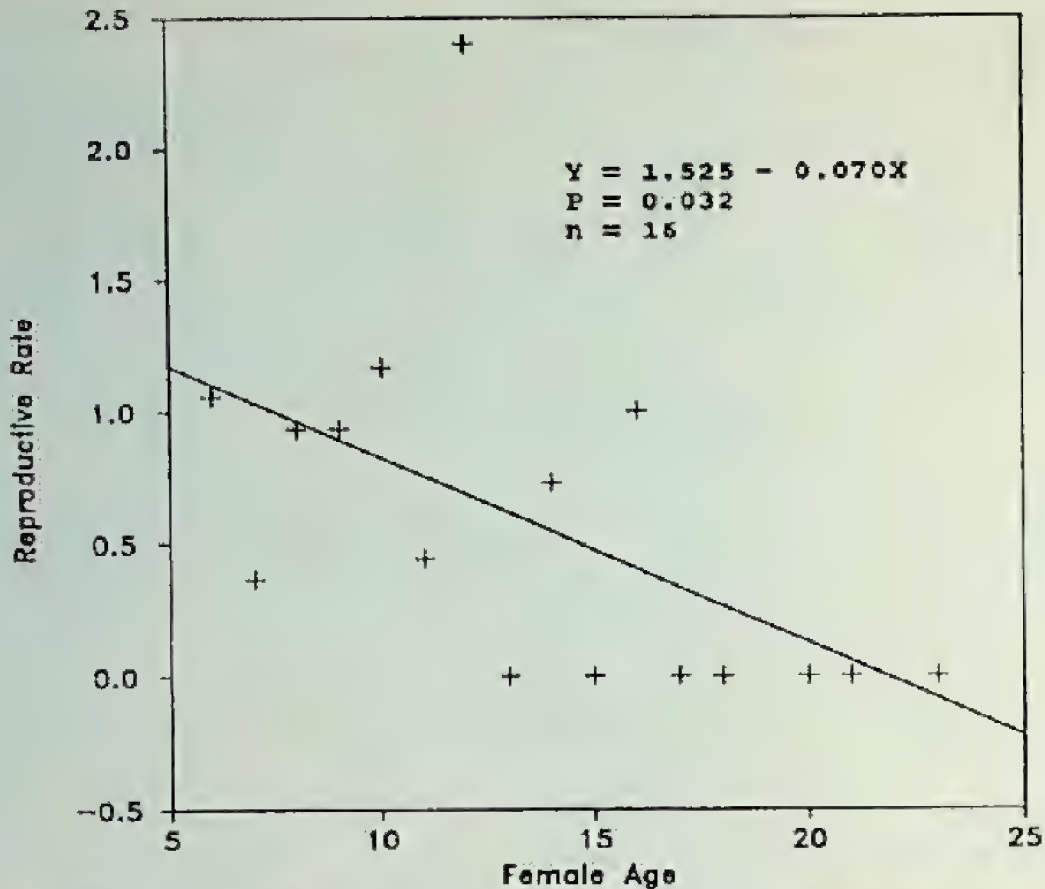


Figure 2. Relationship between reproductive rate and age of female black bears in Yosemite National Park, California, 1974-1988.

(Rogers 1987) and 3.1 in Michigan (Rogers et al. 1976).

Litters in Yosemite's wilderness management area averaged 1.6 cubs and appeared typical of a western black bear population. Litter sizes in developed areas ranged from among the highest reported for a western black bear population (2.0) during the first 10 yr of the program to the lowest (1.3) in the last 5 yr. The decline in litter size coincided with the installation of bear-proof food storage lockers in developed campsites and may have occurred because of a reduction in the availability of human foods.

Age of first reproduction of wild bears averaged 4.7 to 7.5 yr in western states (Jonkel and Cowan 1971, Beecham 1980, Reynolds and Beecham 1980). Collins (1974, cited by Bunnell and Tait 1981) reported an average age of first reproduction of 4.2 yr in North Carolina. Rogers (1987) documented an average first-reproduction age of 6.3 yr in Minnesota. Captive bears and those on diets supplemented by human food had much younger ages of first reproduction. Rogers (1987) reported bears feeding at garbage dumps reproduced at an average age of 4.4 yr. Captive bears produced litters at age 3 (Stickley 1961, cited by Jonkel and Cowan 1971; Rogers 1976). Two known-age bears in Pennsylvania on very high quality diets each bred at 1.5 yr and produced cubs at age 2 (Alt⁸ 1989).

The average age of first reproduction of 4.1 yr suggests that bears using Yosemite's developed area were not nutritionally stressed. The increasing time

⁸Alt, G. 1989. Reproductive biology of female black bears and early growth and development of cubs in northeastern Pennsylvania. Ph.D. Dissertation. West Virginia University, Morgantown, West Virginia, USA.

trend in age of first reproduction is consistent with reduction of human food availability for bears in developed areas and supports the findings of decreasing litter size.

The proportion of adult females producing cubs in a given year appears highly variable within populations, as expected for an alternate-year breeder. It has ranged from 16% in a declining population in Montana (Jonkel and Cowan 1971) to 48% in Virginia (Stickley 1961, cited by Jonkel and Cowan 1971). Rogers (1976) reported 33% to 59% of adult females bred in Minnesota, depending on food availability. Roger's figures are dependent on the lack of breeding the year previous to the year of high quality diet, in order to exceed the theoretical maximum of 50% for an alternate-year breeder. The lack of decline in proportion of females with litters in Yosemite National Park over the 15-yr study indicated that bears may not have experienced significant nutritional stress despite the change in food supply.

The time between litters averaged >3 yr in western black bear populations (Jonkel and Cowan 1971, calculated by Bunnell and Tait 1981; Reynolds and Beecham 1980). In eastern populations, the interval averaged 2 yr in North Carolina (Collins 1974, cited by Bunnell and Tait 1981) and 2.3 yr in Minnesota (Rogers 1987). Rogers found bears whose diets were supplemented with human food averaged 2 yr between litters, the theoretical minimum for the species.

If adjustments are made for the age of first and last reproduction, the reciprocal of the proportion of females with litters should approximate the average interval between litters. Without such adjustments, it should overestimate the interval slightly. The average of 42% of adult females accompanied by litters implies there should be approximately 2.4 yr between litters in Yosemite's developed areas. This figure may be more realistic than the calculated 2.1-yr interval because of the few adult non-breeders. It is still shorter than that found in other western populations and is indicative of a high quality diet. With 33% of adult females accompanied by litters in wilderness, the probable interval between litters is 3 yr, the same as the average for other western populations.

Reproductive rate is a function of litter size and the proportion of females producing litters each year. It is the single parameter that best reflects the total reproductive fitness of a population. Reynolds and Beecham (1980) reported a reproductive rate of 0.782 for black bears in Idaho. A reproductive rate of 0.265 was calculated from data for a declining population in Montana (Jonkel and Cowan 1971). Rogers (1987) suggested reproductive rates ranged from 0.904 to 1.62, depending on food availability, for a Minnesota population.

The lack of decline in reproductive rate in the developed areas was due to the nonsignificant increase in the proportion of females with litters offsetting the decline in litter size and increase in age of first reproduction. It suggests that adult females obtained sufficient human food to prevent a net decrease in productivity during the 15 yr of the study in spite of efforts to reduce human food availability. As the National Park Service continues to reduce human food availability in developed areas, a decrease in the proportion of females with litters should result in a decline in reproductive rate.

Reports of black bears producing litters at ages as high as 27 (Poelker and Hartwell 1973) and 32 yr (Sauer 1975) have prompted conclusions that female black bears maintain reproductive competency almost throughout life (Bunnell and Tait 1981). My study documents that productivity decreased with increased female age in Yosemite black bears. Productivity did not cease, however, as evidenced by the capture of a 22-yr-old female with twin cubs in 1989.

ACKNOWLEDGMENTS

I thank E. Garton, J. van Wagtendonk, J. Peek, A. LeCount, S. Thompson, L. Rogers, G. Hayward, R. Steinhorst, P. McLean, C. McLaughlin, T. Burton, and six anonymous referees for reviewing this paper. Many dedicated National Park Service employees spent long hours capturing bears and gathering information and are greatly appreciated. D. Graber provided a portion of the data for the first 5 yr of the study. This project was funded in part by the Yosemite Fund and the National Park Service.

LITERATURE CITED

- Barbour, M.G. and J. Major, editors. 1977. Terrestrial vegetation of California. John Wiley and Sons, New York, New York, USA.
- Beecham, J. 1980. Some population characteristics of two black bear populations in Idaho. *International Conference on Bear Research and Management* 4:201-204.
- Bunnell, F.L. and D.E.N. Tait. 1981. Population dynamics of bears - implications. Pages 75-98 *in*: C.W. Fowler and T.D. Smith, editors. *Dynamics of large mammal populations*. John Wiley & Sons, New York, New York, USA.
- Collins, J.M. 1974. Some aspects of reproduction and age structures in the black bear in North Carolina. *Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissioners* 27:163-170.
- Erickson, A.W. and J. E. Nellor. 1964. Breeding biology of the black bear. Pages 1-45 *in*: A.W. Erickson et al., editors. *The black bear in Michigan*. Michigan State University Research Bulletin 4.
- Graber, D.M. and M. White. 1983. Black bear food habits in Yosemite National Park. *International Conference on Bear Research and Management* 5:1-10.
- Grinnell, J. and T.I. Storer. 1924. *Animal life in the Yosemite*. University of California Press, Berkeley, California, USA.
- Harms, D.R. 1977. Black bear management in Yosemite National Park. *Proceedings of the Western Association of State Game and Fish Commissioners* 57:159-181.
- Harms, D.R. 1980. Black bear management in Yosemite National Park. *International Conference on Bear Research and Management* 4:205-212.
- Hastings, B.C. and B.K. Gilbert. 1987. Extent of human-bear interactions in the back country of Yosemite National Park. *California Fish and Game* 73:188-191.
- Jonkel, C.J. and I. McT. Cowan. 1971. The black bear in the spruce-fir forest. *Wildlife Monographs* 27.
- Keay, J.A. 1995. Accuracy of cementum age assignments for black bears. *California Fish and Game* 81:113-121.

- Keay, J.A. and J.W. van Wagtendonk. 1983. Effect of Yosemite back country use levels on incidents with black bears. *International Conference on Bear Research and Management* 5:307-311.
- Keay, J.A. and M.G. Webb. 1989. Effectiveness of human-bear management at protecting visitors and property in Yosemite National Park. Pages 145-154 *in*: M. Bromley, editor. *Bear-people conflicts. Proceedings of a Symposium on Management Strategies*, Northwest Territories Department of Renewable Resources, Northwest Territories, Canada.
- LeCount, A.L. 1982. Characteristics of a central Arizona black bear population. *Journal of Wildlife Management* 46:861-868.
- Lindzey, F.G. and E.C. Meslow. 1977. Population characteristics of black bears on an island in Washington. *Journal of Wildlife Management* 41:408-412.
- Piekielek, W. and T.S. Burton. 1975. A black bear population study in northern California. *California Fish and Game* 61:4-25.
- Poelker, R.J. and H.D. Hartwell. 1973. Black bear of Washington. Washington State Game Department, Biological Bulletin No. 14.
- Reynolds, D.G. and J.J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho. *International Conference on Bear Research and Management* 4:181-190.
- Rogers, L.L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. *Transactions of the North American Wildlife and Natural Resource Conference* 41:431-438.
- Rogers, L.L. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. *Wildlife Monographs* 97.
- Rogers, L.L., D. W. Kuehn, A. W. Erickson, E. M. Harger, L. J. Verme, and J. J. Ozoga. 1976. Characteristics and management of black bears that feed in garbage dumps, campgrounds, or residential areas. *International Conference on Bear Research and Management* 3:169-175.
- Rust, H. J. 1946. Mammals of northern Idaho. *Journal of Mammalogy* 27:308-327.
- Sauer, P. R. 1975. Relationship of growth characteristics to sex and age for black bears from the Adirondack region of New York. *New York Fish and Game Journal* 22:81-113.
- Stickley, A. R. 1961. A black bear tagging study in Virginia. *Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissioners* 15:43-54.
- Wilkinson, L. 1988. SYSTAT: The system for statistics. SYSTAT, Inc. Evanston, Illinois, USA.

Received: 3 January 1995

Accepted: 20 October 1995

IN MEMORIAM

DAVID C. ZEINER

California's wildlife lost an important advocate on October 1, 1995 when David C. Zeiner died suddenly of a brain aneurysm at the age of 63. Dave was highly regarded as a biologist by his peers and was well known within the California Department of Fish and Game, other government agencies, academia, and the private sector. His devotion to California's wildlife resources was demonstrated by his dedication to his profession, his membership in The Wildlife Society, and the countless hours spent in the field pursuing his avocations of fishing, diving, and hunting.

Dave made many invaluable and lasting contributions to conserving and managing these resources over his 37-yr career, almost all of it with the Department of Fish and Game. He was involved with many issues, including abalone, sea otters, wetlands, and the California Wildlife Habitat Relationships System (CWHR). Dave played a substantial role in designing the current-day abalone iron to minimize fatalities from failed harvest attempts. He promoted zone management concepts for the sea otter prior to its listing as a threatened species in California. Dave is probably best remembered for his position as the CWHR Coordinator, where he oversaw the design, management, and use of the most definitive source of information on the state's terrestrial vertebrates. One of his most significant accomplishments was editing and compiling *California's Wildlife*, a 1,400-plus page, three-volume CWHR publication describing the life history, distribution, and management status of almost 650 species of California fauna.

Dave graduated in June 1957 with a B.S. in Natural Resource Management from California Polytechnic State University, San Luis Obispo. He began his career that same year as a Fish and Game Seasonal Aid in Fresno and was soon promoted to Fish and Game Assistant at the Los Banos Wildlife Area. In 1961, Dave again promoted, this time to Brawley as a Game Manager I. In 1964, he transferred to the Department's Delta Fish and Wildlife Protection Study in Stockton and worked on soil-water-salt relationships of waterfowl food plants in the Suisun Marsh. In 1966, Dave left the Department for a 4-month stint as a Recreation Planner II with the Department of Parks and Recreation, but he came back to Fish and Game as a Wildlife Manager II in Sacramento later that year. In 1967, he became an Associate Wildlife Manager/Biologist and he continued to work in Sacramento until he took the position as the CWHR Program Coordinator in early 1984 at the Wildlife Investigations Laboratory in Rancho Cordova. Dave remained in that position until his retirement in February 1994. He received his 25-yr service award in July 1982.

Dave is survived by his wife, Shirley, and daughters Patricia and Debra. Upon retirement, Dave and Shirley moved from Sacramento to Kailua Kona, Hawaii, where Dave had dreamed of retiring. Dave is missed and fondly remembered by those who knew and worked with him for his contributions to conserving California's wildlife.

--Barrett A. Garrison, Wildlife Management Division, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814.

INSTRUCTIONS FOR AUTHORS

California Fish and Game is a professional, scientific journal devoted to the conservation and understanding of California's flora and fauna. Original manuscripts dealing with California species or providing information of direct interest and benefit to California researchers and managers are welcome.

MANUSCRIPTS: Refer to the CBE Style Manual (5th Edition) and a recent issue of *California Fish and Game* for general guidance in preparing manuscripts. Specific guidelines are available from the Co-Editors-in-Chief.

COPY: Use good quality 215 x 280-mm paper. Double-space throughout with 25-mm margins. Do not hyphenate at the right margin or right-justify text. Authors should submit four good copies of their manuscript, including tables and figures, to the Co-Editors-in-Chief. An electronic copy of the manuscript on diskette in word processor format will be required with the final accepted version.

CITATIONS: All citations should follow the name-and-year system. See a recent issue of *California Fish and Game* for the format of citations and Literature Cited. Completely spell out publication and periodical names in Literature Cited. Avoid references to unpublished literature.

ABSTRACTS: Every article, except notes, must be introduced by an abstract. Abstracts should be about one typed line per typed page of text. In one paragraph describe the problem studied, most important findings, and implications of the results.

TABLES: Start each table on a separate page and double-space throughout. Do not use vertical rules. Use tabs, not the spacebar, to space between columns. Footnotes in tables should be consecutive lowercase letters, with the sequence beginning again in each table.

FIGURES: Consider proportions of figures in relation to the usable page size of *California Fish and Game* (117 x 186 mm). Figures, including captions, cannot exceed this size. Figures and line-drawings should be clear, with well-defined lines and lettering. Lettering style should be the same throughout and large enough that it is readable when reduced to finished size. Type figure captions on a separate page. Photographs of high-quality with strong contrasts are accepted and should be submitted on glossy paper. On the back and top of each figure or photograph, lightly write the figure number and senior author's last name. Be prepared to provide high-quality, scannable, original figures or graphics files on diskette with the final accepted manuscript.

PAGE CHARGES AND REPRINTS: All authors will be charged \$40 per printed page and will be billed before publication of the manuscript. Explicit acceptance of page charges should be included in the submittal letter. Authors will receive a reprint order form along with the galley proof.

CALIFORNIA
FISH-GAME



Editor, *CALIFORNIA FISH AND GAME*
California Department of Fish and Game
1416 Ninth St., Sacramento, CA 95814

BULK RATE
U.S. POSTAGE
PAID
Sacramento, CA.
Permit No. 949

770